

The American Mineralogist

*Journal of the Mineralogical
Society of America*

Vol. 34

MARCH-APRIL, 1949

Nos. 3 and 4

Contents

Prospect of mineralogy.....	M. A. Peacock	135
The frequency of twin types in quartz crystals.....	H. R. Gault	142
The unit cell and space group of lindgrenite.....	William H. Barnes	163
Some comments on the Buerger precession method for the determination of unit cell constants and space groups.....	William H. Barnes	173
Crystallography of spangolite.....	Clifford Frondel	181
Retgersite, $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$, a new mineral..	Clifford Frondel and Charles Palache	188
Thermal study of rhodochrosite.....		
..... J. Laurence Kulp, Harold D. Wright and Ralph J. Holmes		195
What is a mineral?.....	Alexander N. Winchell	220
A definition of Euclidean geometrical symmetry.....	Henri Bader	226
The Aggie Creek meteorite from Seward Peninsula, Alaska.....	Edward P. Henderson	229
Presentation of the Roebling Medal of the Mineralogical Society of America to William Lawrence Bragg.....	George Tunell	235
Acceptance of the Roebling Medal of the Mineralogical Society of America.....	W. L. Bragg	238
Memorial of A. Lacroix.....	Jean Orcel	242
Memorial of Alfred Church Lane.....	Esper S. Larsen, Jr.	249
Memorial of James Greenfield Manchester.....	Gilman S. Stanton	253
Memorial of Lewis Gardner Westgate.....	John H. Melvin	256
Memorial of Herbert Percy Whitlock.....	Frederick H. Pough	261
Proceedings of the twenty-ninth annual meeting of the Mineralogical Society of America at New York, N. Y.....	C. S. Hurlbut, Jr.	267
Conference on the teaching of crystallography.....		
J. D. H. Donnay, D. Jerome Fisher, Samuel G. Gordon, M. A. Peacock and George Tunell		288
Correspondents, fellows, members and subscribers of the Mineralogical Society of America.....		293
Notes and news: Pseudotachylite of the Antietam quartzite.....	J. L. Anderson	331
A new locality for ludlamite.....	Jewell J. Glass and John S. Vhay	335
Proceedings of Societies: Mineralogical Society (London).....		337
New mineral names.....		339
Announcement of annual meeting and nominations of officers.....		340



EDITOR

WALTER F. HUNT

ASSOCIATE EDITORS

MICHAEL FLEISCHER, SAMUEL G. GORDON, ESPER S. LARSEN,
AUSTIN F. ROGERS, M. N. SHORT AND GEORGE TUNELL

Published bi-monthly by the Society

Mineralogical Society of America

ASSOCIATED WITH THE GEOLOGICAL SOCIETY OF AMERICA

- President:** John W. Gruner, University of Minnesota, Minneapolis, Minnesota.
Vice President: J. D. H. Donnay, The Johns Hopkins University, Baltimore, Maryland.
Secretary: C. S. Hurlbut, Jr., Harvard University, Cambridge, Massachusetts.
Treasurer: Earl Ingerson, U. S. Geological Survey, Washington 25, D.C.
Editor: Walter F. Hunt, University of Michigan, Ann Arbor, Michigan.
Councilors: Joseph Murdoch, University of California at Los Angeles, Los Angeles, California.
 H. H. Hess, Princeton University, Princeton, New Jersey.
 Clifford Frondel, Harvard University, Cambridge, Massachusetts.
 Lewis S. Ramsdell, University of Michigan, Ann Arbor, Michigan.
 M. A. Peacock, University of Toronto, Toronto, Canada.

The enlarged issues of this journal for 1949 are made possible by a grant from the Penrose Fund of the Geological Society of America.

The American Mineralogist—Journal of the Mineralogical Society of America

A journal containing articles on mineralogy, crystallography, petrography, and allied sciences, issued every two months. Contributions are invited from everyone. Office of Publication, Mineralogical Laboratory, Ann Arbor, Mich.

The general conduct of the journal is in the hands of the Editor, **Walter F. Hunt**, Ann Arbor, Michigan. The council of the Mineralogical Society has appointed the following board of associate editors, to whom should be sent articles dealing with the special subjects indicated:

Michael Fleischer, U. S. Geological Survey, Washington, D.C., *New minerals*.
Samuel G. Gordon, Academy of Natural Science, Philadelphia, Pa., *Mineral museums*.
Esper S. Larsen, Harvard University, Cambridge, Mass., *Optical crystallography*.
Austin F. Rogers, Stanford University, California, *Geometrical crystallography*.
M. N. Short, University of Arizona, Tucson, Arizona, *Mineralography*.
George Tunell, University of California at Los Angeles, *Structural crystallography*.

Contributors of leading articles are given without charge 100 reprints (without covers) of their article. If additional reprints are desired these can be purchased at the following rates:

Pages	1-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32	Covers
<i>Copies</i>									
25	\$3.50	\$5.00	\$ 8.00	\$ 9.50	\$11.00	\$13.00	\$15.00	\$16.00	\$4.90
50	3.80	5.55	8.80	10.40	12.10	14.20	16.40	17.50	5.50
75	4.10	6.10	9.60	11.30	13.20	15.40	17.80	19.00	6.10
100	4.40	6.65	10.40	12.20	14.30	16.60	19.20	20.50	6.70
Addl. C's	1.20	2.20	3.20	3.60	4.40	4.80	5.60	6.00	2.40

Cover Composition \$1.55.

Sent to all members and fellows of the Mineralogical Society of America. Subscription price, \$4.00 per year (single copies of normal issues, \$1.00 plus postage).

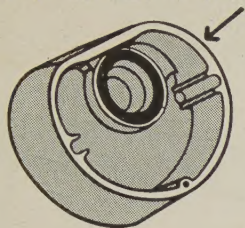
Entered as second class matter at the post office at Menasha Wis., under Act of March 3, 1879. Acceptance for mailing at the special rate of postage provided for in section 1103, Act of Oct. 3, 1917, paragraph 4 section 429 P. L. & R. authorized March 13, 1922.

Notices of change of address, orders, and remittances should be sent to Dr. Earl Ingerson, U.S. Geological Survey, Washington 25, D. C.

Printed by the George Banta Publishing Company, Menasha, Wisconsin

PATENTED

SEALED-IN PRISMS



... prevent dust and other foreign material injurious to precision optics from sifting down through eyepieces into prisms and nosepieces. Patented design of the housing features a Neoprene ring which makes contact with the top surface of the Porro prism. Prism assemblies are protected and kept dust-tight for the full life of the instrument.

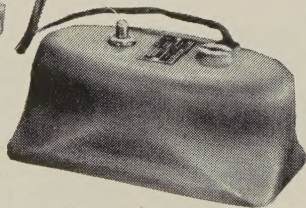
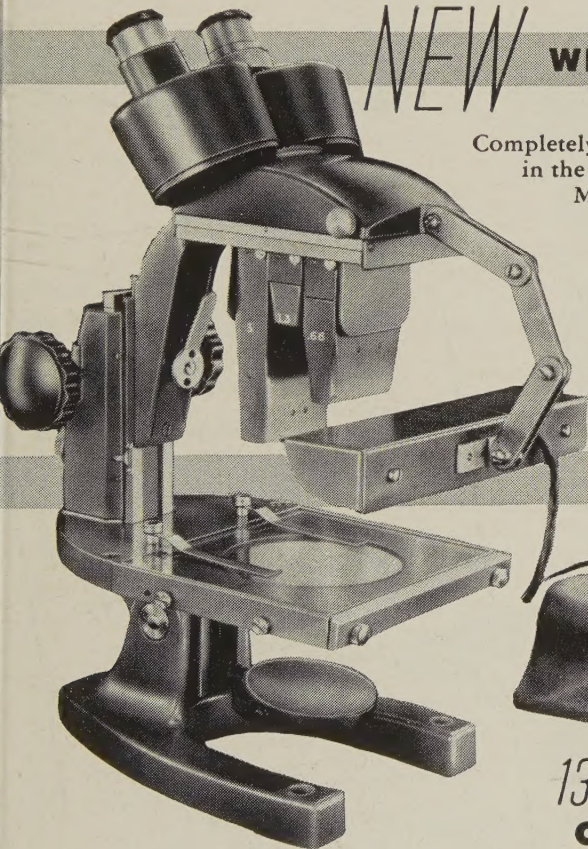
NEW

WIDER FIELDS

Completely re-designed optical system in the Bausch & Lomb Stereoscopic Microscopes offer wider fields.

You are given a larger area to examine without loss of critical focus . . . full value in the realization of the three dimensional image. To appreciate this amazing difference you must see it!

PLUS...



13 OTHER POINTS OF SUPERIORITY

No other instrument has so many superior features. Unsurpassed Bausch & Lomb Optical Engineering makes these the *finest stereoscopic microscopes in the world.*

WRITE

for free literature and demonstration. Bausch & Lomb Optical Co., 676-D St. Paul St., Rochester 2, N. Y.

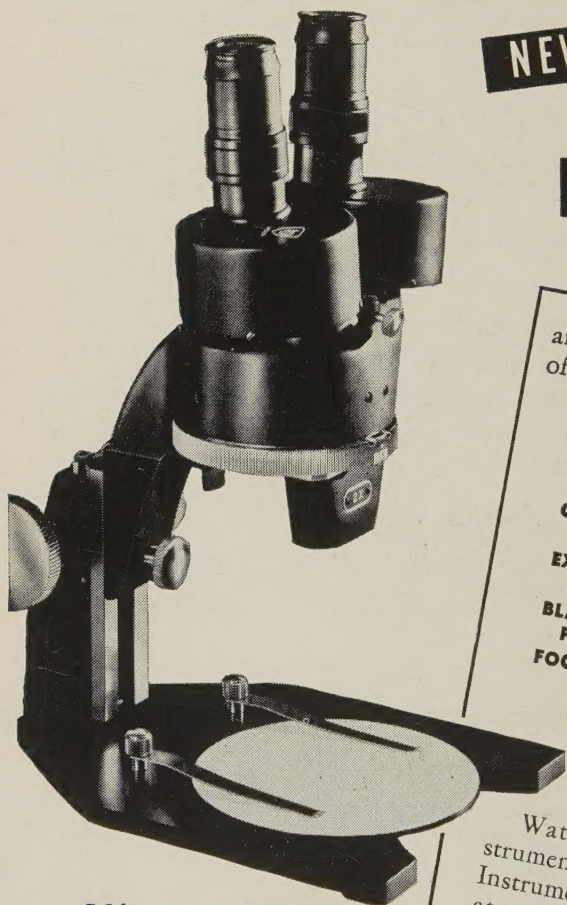
Bausch & Lomb Stereoscopic Wide Field Microscopes

A **NEW** SPENCER STEREOSCOPIC MICROSCOPE

NEW Double Revolving Nosepiece

NEW Black Satin-Smooth Finish

NEW Platen Type Stage



Microscope No. 21

PRICES START AT \$194.00

including optics

[Model illustrated—No. 21X with 1.0X and 2.0X paired Objectives, 9X paired Wide Field Eyepieces and cabinet—is priced at \$254.00.]

and all of these time-proven features of Spencer Stereoscopic Microscopes:

UNUSUALLY WIDE, FLAT FIELDS
ENHANCED STEREOSCOPIC EFFECT
from paired objectives converging at 12°

COMFORTABLE VISION through normal eyetube convergence of 8°

EXTENDABLE DOVETAIL BODY SLIDE
supplements focusing mechanism

BLACK AND WHITE REVERSIBLE STAGE PLATEN

FOCUSING SLIDWAYS GROOVED to retain lubricant

DUSTPROOF NOSEPIECES
protect objectives

DUSTPROOF GEARING for interpupillary distance control

Watch for this outstanding instrument. See your AO Scientific Instrument Distributor or for literature write Dept. P7, American Optical Company, Scientific Instrument Division, Buffalo 15, N. Y.

Makers of Microscopes for over 100 Years



SPENCER

6 important books for mineralogists

MINERALS AND HOW TO STUDY THEM

By the late Edward S. Dana. Revised by Cornelius S. Hurlbut, Jr., Harvard University.

This book retains the aim of its widely-used predecessor—to present mineralogy for the beginner. All present-day data are included. Minerals are arranged according to the almost universally accepted chemical classification.

3rd Edition, Jan. 1949

323 pages

384 illus.

\$3.90

POPULAR GEMOLOGY

By Richard M. Pearl, Colorado College.

In popular language this book presents the most recent accurate knowledge about the world of gems. It is the only book on gems to include a separate chapter on fluorescence and a special chapter on quartz and other silica gems.

1948

316 pages

116 illus.

\$4.00

ROCKS AND ROCK MINERALS

By the late Louis V. Pirsson and Adolph Knopf, Yale University.

For an accurate source of information on petrology on the megascopic level, try this third edition. Significant chemical analyses of rocks with their mineral composition and specific gravity are given, where helpful, throughout the book.

3rd Edition, 1947

349 pages

108 illus.

\$4.00

ERUPTIVE ROCKS

By S. James Shand, Columbia University

This book in its third edition offers a complete classification and nomenclature of eruptive rocks and their relation to ore deposits. The concept of rock types is based on chemistry of silicate systems.

3rd Edition, 1948

488 pages

illus.

\$7.50

IGNEOUS MINERALS AND ROCKS

By Ernest E. Wahlstrom, University of Colorado.

Professor Wahlstrom presents a thorough treatment of the principles of igneous petrography and offers a unique system of nomenclature for igneous rocks. Tables for identification of minerals—their properties and composition—are included.

1947

367 pages

132 illus.

\$5.50

PRINCIPLES OF MICROPALAEONTOLOGY

By Martin F. Glaessner, Chief Paleontologist, Australasian Petroleum Co.

This volume covers the whole field of micropaleontology from biology and protistology through a considerable amount of morphological and systematic paleontology to advanced biostratigraphy. It is abundantly illustrated and documented.

1947

296 pages

illus.

\$6.00

JOHN WILEY & SONS, Inc.,

440 Fourth Avenue

New York 16, N.Y.

Rutile — THE GEM OF THE HOUR

Rutile is a reality. RUTILE IS THE MOST AMAZING GEM KNOWN. It has a much higher refractive index than Diamond. In the sunlight sparks of refractive fire are thrown out by every facet. It displays all the colors of the rainbow in a dazzling play of color.

IT MUST BE SEEN TO BE APPRECIATED

Nothing has created such intense interest and excitement as the showing of these gems. A recent issue of *The Saturday Evening Post* gave them a prominent write-up. Cut gems are now actually in stock and available for immediate delivery.

ROUND BRILLIANT CUT GEMS ARE PRICED AT:

1/2 to 3/4 carat gems at \$12.50 per stone

1 carat gems at \$15.00 per stone

1 1/2 to 2 1/2 carat gems at \$12.50 per carat

3 carat and larger gems at \$10.00 per carat

Add 20% Federal Excise Tax and California Sales Taxes to above prices.

PRICES ON ROUGH BOULES, BOULE SECTIONS and PREFORMS ON REQUEST.

DEALERS INQUIRIES SOLICITED

MEN'S RINGS, LADIES' RINGS, AND EARWIRES MOUNTED WITH RUTILE AVAILABLE IN GOLD AND PLATINUM.

GRIEGER'S "ENCYCLOPEDIA AND SUPER-CATALOG OF THE LAPIDARY AND JEWELRY ARTS" is as sensational as the NEW RUTILE GEMS.

Read what purchasers of this new book are saying:

"I would still buy it at \$3.00 to \$5.00 as it contains as much, if not more, meaty information for the lapidary and jeweler than any of the books on the market selling in that range."

"It is the only satisfactory catalog of lapidary supplies and materials that I have ever seen. It is superbly illustrated and beautifully printed."

Send \$1.00 for this 160-page bound book 9 x 12" in size. It is sold for only a portion of its actual cost. May be returned for full cash refund if not satisfactory.

Grieger's

1633 E. WALNUT STREET
PASADENA 4, CALIFORNIA

W. HAROLD TOMLINSON

Petrographic Laboratory

260 N. ROLLING RD., SPRINGFIELD, PA.

ROCK SECTIONS

ORIENTATED MINERAL SECTIONS

INDEX MEDIA

LIQUID IMMERSION MEDIA—Original series, colorless, odorless, stable, exact specified indices, range Nd 1.41 to 1.65, in applicator vials		\$1.50 per ounce
Set of above series, steps of .01, in twenty-five 1-ounce applicator vials, with cabinet		\$27.50
Methylene Iodide series, Nd 1.66 to 1.78		\$2.00 per $\frac{1}{8}$ fl. oz.
Set of thirty-eight Immersion Media Nd 1.41 to 1.78 in steps of .01, in $\frac{1}{8}$ fl. oz. applicator vials with cabinet		\$35.00

EVERYTHING PRACTICABLE IN INDEX MEDIA

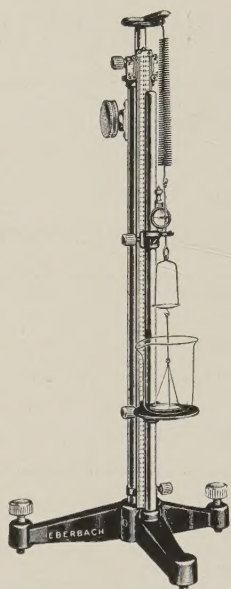
J. T. Rooney, P.O. Box 358, Buffalo, N.Y.

CRYSTALLOGRAPHY

Specializing in choice crystals, singles, groups, from world wide sources.
Catalog free.

V. D. HILL

Complete Gem & Mineral Establishment
Route 7-F, Box 188, Salem, Oregon



KRAUS JOLLY BALANCE

For Speedier Specific Gravities

This professional model made by Eberbach is widely used for rapid determination of specific gravities in mineralogical and petrographic laboratories.

The Kraus Jolly balance simplifies the determination of specific gravity; only two readings and a division are necessary; older form of the balance require more extensive computation. The balance is especially well adapted for the rapid and accurate determination of specific gravity of solids, such as minerals, rocks, coal, precious stones, etc.

A complete description of the Kraus Jolly balance is available on request.

Eberbach & Son
ANN ARBOR, MICH.

LABORATORY
APPARATUS
& SUPPLIES
SON COMPANY
ESTABLISHED 1943

The Recently Prepared 200 page Author-Subject INDEX TO VOLUMES 21-30, 1936-1945, of THE AMERICAN MINERALOGIST

by
EARL INGERSON, Geophysical Laboratory
and
MICHAEL FLEISCHER, U.S. Geological Survey
is now available

The price is \$2.00 to members and subscribers and \$3.00 to non-members. The Treasurer will be glad to receive your order now. Address, Dr. Earl Ingerson, U.S. Geological Survey, Washington 25, D.C.

WANTED

The Mineralogical Society of America is in special need of certain issues of *The American Mineralogist* to complete full sets. The Society will pay \$1.00 each for the following issues if returned to the Editor in such condition as to make resale possible.

Year 1942

January

February

Year 1943

March

Year 1944

January-February

Year 1945

March-April

Also Vol. 1 is desirable.

Address: W. F. Hunt, Editor: Mineralogical Laboratory, University of Michigan, Ann Arbor, Michigan.

THE AMERICAN MINERALOGIST

JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

Vol. 34

MARCH-APRIL, 1949

Nos. 3 and 4

PROSPECT OF MINERALOGY*

M. A. PEACOCK, *University of Toronto, Canada.*

On this occasion I might follow the usual course and devote most of this address to a review of recent developments in mineralogy, with emphasis on that part of the subject in which I have taken some part, and conclude with the hope that the good work may continue on similar lines. Such a course is suitable in the evolutionary periods of the development of a science when the extent of the field of study and its relations to adjoining fields appear to be well-defined and generally accepted; when the underlying theories of the subject have been consolidated into definite doctrine which no longer requires defense; when important discoveries are rare and observations lead mainly toward the refinement of existing knowledge; when methods of observation, description, classification, and interpretation are established and further effort results chiefly in the improvement of numerical detail, systems of notation, and style of presentation; when comprehensive treatises can be compiled with deliberation and prospect of completeness; and when, as a consequence, scientific output can be fairly predicted as the product of trained men and working hours.

But these lengthy periods of relatively placid scientific industry are occasionally interrupted by rude disturbances when the proper territory of a science and its boundaries with adjacent fields are subject to revision and dispute; when established theories are shaken by bold new hypotheses and speculations which are advanced on the one hand and rejected on the other; when every day brings new discoveries and there is no time for refined observations; when new instruments are devised, new notations are improvised, and good form and polished style give way to rougher and readier modes of presentation; when the author of a comprehensive work is bedevilled by current changes of viewpoint and notation and an unceasing flood of new results which tend to make the first part of such a work out-of-date before the last has been prepared; and when steady satisfaction with accumulating scientific achievement on established

* Address of the retiring President of the Mineralogical Society of America, delivered at the twenty-ninth annual meeting of the Society in New York City, November 12, 1948.

lines gives place to the occasional exhilaration of notable discoveries in the course of arduous efforts in new directions. In mineralogy we are at present in the midst of such a period of revolution, and at such a time the usual contented view of the past and cheerful look to the future will be of no great value. It will be more useful, I think, to attempt to survey the situation more widely, to try to assess the trend of the rapid new developments, and to endeavor to coordinate the new activities and results with the old in a logical sequence.

Before looking more closely at the present situation let us recall a former revolution in mineralogy which sprang from a single discovery in crystal physics, namely the double refraction of Iceland Spar and the use of this effect in the Nicol prism to make a polarizing microscope. At first, physicists developed the beautiful theory of crystal optics on the basis of the optical behaviour of natural crystals and crystal plates, providing for the first time a way of looking through a mineral and seeing, as it were "through a glass darkly," not the actual crystal structure but certainly effects which are intimately related to the architecture of the crystal. Soon the mineralogists adopted the theory and methods of optical crystallography as their own; the optical properties of all the non-opaque minerals were eventually determined and with the noteworthy development of the immersion method for the approximate determination of optical properties on microscopic fragments, the fruits of this important development were incorporated in a serviceable method for the identification of minerals. At the same time the polarizing microscope gave rise to the study of rocks in thin sections and ores in polished surfaces, leading to the development of petrography and ore microscopy.

When minerals are studied mainly in thin sections, or polished surfaces, or crushed fragments there is some danger of never learning to know them in their proper crystal forms; he who has seen feldspar, pyroxene, epidote, pyrite, pyrrhotite or magnetite only in sections or grains, is like one who has seen a salmon only in the can. In the end, of course, mineralogy was greatly enriched by the methods and results of crystal optics, and optical mineralogy and mineralography have become smoothly incorporated in regular mineralogical doctrine.

The latest revolution in mineralogical history, and I think without question the most profound, likewise originated with the discovery of a new physical effect obtained with a mineral crystal, namely the production of a regular diffraction pattern by the passage of a beam of x-rays through a crystal of zincblende on to a photographic plate. This time the new radiation fully illuminated the internal structure of the crystal. When suitable apparatus was devised and appropriate methods of measurement and mathematical treatment were worked out it was clear that the

result was no less than the determination of the actual atomic arrangement within the crystal. In the development of this subject the late Sir William Bragg and his son, now Sir Lawrence Bragg, our distinguished Roebing Medallist, played the leading part; and for about two decades after the initial experiment in 1912 the analysis of structures of ever increasing complexity was carried out, mainly on minerals, by the Braggs, their students, and their followers. Some details of this work have just been given by Dr. Tunell and Sir Lawrence at the luncheon table.

Mineralogists as a body were slow to appreciate the full meaning of the new work; the symmetry notation used by the physicists was unfamiliar, their lists of lattice planes seemed strange, and the complex arrangements of spheres in space appeared to have little relation to the familiar properties of minerals. So strong was the classical conception of an axial cross within a crystal, rather than a crystal lattice, that it took years before it was generally recognized that a properly chosen axial cross is nothing but the edges of the properly chosen unit cell of the structural lattice. Similarly it took time to realize that a crystal face is but the limiting plane of a set of equidistant planes traversing the entire crystal and that the indices of a crystal face are most conveniently defined as the numbers of parts into which the corresponding set of planes cuts the edges of the lattice cell. Mineralogists have been slow, too, to admit that the lattice type and even the space-group can often be recognized and reliably predicted from the development of the crystal forms.

In the same way the belief in chemical composition in simple rational proportions has resulted in some reluctance to accept the often irrational numbers of atoms found in the unit cell by calculation from the chemical analysis, the cell volume, and the density. Isomorphous mutual substitution between atoms of equal valence had already been recognized, but such substitution between atoms of unequal valence, notably silicon and aluminium, irrational cell contents by defect or vacant equipoints, and the distinct leaning away from simple rational proportions in many metallic minerals, are only now gaining wide acceptance.

It is not surprising, therefore, that mineralogists have tended to treat the results of *x*-ray analysis as an appendix to classical mineralogy, rather as the treatment of space-lattices and space-groups used to be given as an appendix to classical crystallography. I think if we were to set out today to arrange the contents of a specific mineral description in the most logical way we would commence with the crystal structure, recognizing that the kinds and number of the atoms in the unit cell, the symmetry of their arrangement, and their particular positions and bonding must underlie and be capable of explaining all the remaining properties of the mineral crystal. Such an arrangement would I believe soon

come to be accepted by mineralogists and it would also appeal to physicists, chemists, metallurgists, and others interested in natural crystalline materials.

In considering the progress of science we cannot overlook the fact that the research of today is being done by the university graduates of yesterday, and that much of this research is usually accomplished in the period of special energy and enthusiasm and relative freedom from burdensome duties that rarely extends more than a decade after graduation. In mineralogy the question therefore is: Who shall teach our selected students the art of x -ray analysis with its formidable recent development of vector and electron density maps and computing devices, and where shall they apply the art to the analysis of mineral structures?

In some mineralogical laboratories the determination of the symmetry, dimensions, and atomic content of the unit cell is already taught at the undergraduate level, and these first steps in x -ray analysis are regular procedure in mineralogical research. The preparation of standard x -ray powder patterns and the identification of minerals by means of such patterns, often on minute samples picked out of ore or rock sections, is also becoming standard practice. However, few teachers of mineralogy would be prepared to give a rigorous course on the physics of x -rays and x -ray diffraction by crystals, and the modern methods of x -ray analysis. The necessary basic instruction in these matters might be offered in a Physics Department or, in larger institutions, in a Department of Crystallography which would serve the needs of students of Physics, Chemistry, Mineralogy, Metallurgy, and Biochemistry, all of whom have direct interest in the subject.

The application of the art of x -ray analysis must clearly be done in mineralogical laboratories. Like the spectrograph and the microscope, x -ray diffraction equipment of the various useful kinds has its proper place in a mineralogical laboratory, and it is to be hoped that convenient devices for the measurement and calculation of the intensities of x -ray reflections may soon become more generally available. With these means the extension of x -ray analysis to such large groups of minerals as the sulfo-salts, the phosphates, and the arsenates offers a promising program of research for suitably prepared graduate students in years to come.

In emphasizing the fundamental nature of crystal structure in mineralogy and the propriety of applying structural methods to the whole field of mineralogy I would guard against using mineral crystals merely as grist for the roentgenographic mill. Rather would I urge the conservation of the classical methods of mineralogical study and the preservation of the great body of accurate information which has been obtained by

the older methods. Today, already, the art of chemical analysis of minerals is almost forgotten. How many competent chemical analysts are there today who for love or money will expend the skill and care that is needed to obtain the chemical composition of a mineral of average complexity, using perhaps a tenth of a gram of material? Very few indeed. There is great need for example and guidance in this matter, and this would be better provided in the university than in a commercial laboratory. Again, the art of crystal measurement on the reflecting goniometer, projection, calculation, and drawing is still cultivated in only a few institutions, and the latest books on crystallography give but the meagrest sketch of this important aspect of mineralogical study. Today, I think, a morphological study should accompany every study of structure to throw further light on the absorbing problem of the relation of crystal form to crystal structure. And yet again, with the wide use of the immersion method in optical mineralogy giving results that are good to 1 or 2 units in the third decimal of refractive indices and 5 or 10 degrees in optic axial angle, the more exact methods of optical mineralogy using cut plates and wedges are almost forgotten. Typical exercises in these methods can be effectively introduced in undergraduate work. The preservation of the results of such neglected methods of research might best be done by specialists who could prepare concise accounts of the theory and practice of a particular method and a critical compilation of the results.

Finally, the reorientation of a science that results from a discovery of fundamental importance, is apt to be accompanied by some reconsideration of its relation to kindred sciences and the redefinition of its proper field as distinct from its common territory with the adjoining sciences. Particular aspects of mineralogy are of interest to chemists, crystallographers, geologists, miners, metallurgists, and others, who are usually concerned with the essential descriptive details of the commoner minerals and simple and effective means for identifying them. Mineralogists have a responsibility in this common territory that can be met by providing simplified mineralogies and determinative schemes which can be used without long study.

Within this common territory, however, remains the proper field of mineralogy in which, as always, the principal interest is in the recognition of all mineral species, the precise determination of their specific properties, and the arrangement of mineral species in a satisfactory classification. This is frankly descriptive natural science. I realize that this designation is sometimes applied with a hint of disparagement, suggesting that the qualifications required for its pursuit are not particularly high and that the results obtained are not particularly valuable.

This must remain a matter of opinion. The full study of a mineral species demands a fair equipment: some knowledge of classical and modern languages properly to appraise the history and synonymy of the species; a knowledge of the theory and practice of geometrical crystallography to measure a crystal on the reflecting goniometer, project the planes, select proper axes and elements, assign indices to the observed forms, calculate elements and angles, and construct a faithful drawing; a knowledge of the theory and practice of x -ray measurements and analysis to permit the determination of the space-group and the dimensions of the unit cell from single crystal photographs and, if necessary, to transform the results of the geometrical work to conform to the structural results; to prepare a properly indexed x -ray powder pattern for the mineral; to determine the atomic content using the specific gravity and the chemical composition; and in favourable cases to fix the parameters of all the atoms; a knowledge of the theory and practice of optical mineralogy to determine, in the case of a transparent mineral, the orientation of the optical ellipsoid with reference to the crystal axes, the values of the principal refractive indices, the optic axial angle, the optic sign, and the absorption, and the variation of these properties with wavelength; and in the case of an opaque mineral to determine the reflecting power, reflection pleochroism, and anisotropism in polished surfaces under the reflecting polarizing microscope; to determine the hardness, the specific gravity, if necessary on a minute sample, and occasionally the magnetic and electric properties; and finally, or perhaps at the outset of the work, to discover the qualitative chemical composition of the mineral by dry and wet tests, perhaps aided by the spectrograph, and to prepare and analyze a clean sample to a summation that comes within one per cent of a hundred. If all this seems easy, do try it sometime. Whether it is worthwhile I shall not dispute.

Next to this basic work, which is the mineralogist's undivided business, comes the study of mineral associations and the concurrent laboratory research which seeks to reproduce single minerals or paragenetically related groups of minerals with a view to finding the physico-chemical conditions under which they may have formed in nature. Great as the importance of this work is, especially in relation to the origin of igneous rocks, pegmatites, and ore deposits, it must be granted that a precise knowledge of the properties of minerals themselves is a prerequisite for work upon their origin.

What is the incentive for work in pure mineralogy? Nothing exalted, I fear: merely curiosity and delight in the Mineral Kingdom, an urge to observe all the properties of each species, be it common or rare, valuable or worthless, with equal precision, to record these observations in style

and form worthy of the elegance of Nature herself, and to bring out relationships that are clearly indicated by the facts of observation.

Special interest and sometimes special pleasure attends the re-examination of those many incompletely defined mineral substances which are relegated to the limbo of doubtful species in descriptive mineralogy. These ill-defined substances must be found to contain either nothing new or something new. With authentic material and better luck or better equipment than that of the original investigator it may prove that the doubtful substance is merely one or more known minerals, and if this is the result we have a useful clarification; or it may prove that the ill-defined material consists wholly or in part of a new species whose properties can be completely ascertained. On a few occasions it has been my good fortune to bring one of these wanderers into the fold, and then I, at least, "rejoiced more of that sheep than of the ninety and nine that went not astray."

This, of course, is not the end of mineralogical research but rather the beginning. As I have indicated, the origin of minerals is of immediate interest to mineralogists. All branches of applied mineralogy are legitimate lines of research, but I am inclined to the view that success in these directions depends mainly on the facts of mineralogy and technology and the financial pressure of governments or business. Intensive work on one or another property of minerals, such as the structure, the morphology, or the optics, will yield information of great detail; but such work begins to lose touch with mineralogy when the interest centres more on the property than on the mineral. In this connection my wife has reminded me of the following story. "Antaeus, the son of Terra, the Earth, was a mighty giant and wrestler whose strength was invincible so long as he remained in contact with his Mother Earth . . . Hercules encountered him, and finding that it was of no avail to throw him, for he always rose with renewed strength from every fall, he lifted him up from the earth and strangled him in the air." Let us keep our feet on the ground and remain strong.

THE FREQUENCY OF TWIN TYPES IN QUARTZ CRYSTALS¹

H. R. GAULT, *Lehigh University, Bethlehem, Pa.*

CONTENTS

Abstract.....	142
Introduction.....	142
Quartz etch figures.....	144
Quartz twin laws.....	146
Procedure.....	150
Results and description of material.....	150
Discussion.....	155
Summary and conclusions.....	159

ABSTRACT

The frequency of twin types and the handedness were determined for 1,179 crystals from six localities by the use of etch figures developed with hydrofluoric acid. It is shown that twinned quartz crystals are much more common than untwinned and that the frequencies of twin types and the ratios between twin types vary from locality to locality. It is suggested that crystals twinned according to both the Dauphiné and Brazil laws should be called "Dauphiné-Brazil" twins rather than by the names that have been previously applied. The local variations of twin ratios are thought to be a reflection of geologic environment.

INTRODUCTION

Some years ago while engaged in etch-figure work with the late Dr. A. P. Honess, it became desirable to etch and study a few low-quartz² crystals from two localities. The crystals from the first locality showed considerably more twinning than those from the second, although the unetched crystals gave no indication of any twinning. A search through the literature disclosed many articles on twinning in quartz but there were few statistical data on the frequency distribution of twin types and of right- and left-handed crystals. Further studies were made on additional crystals from these two localities and from four others in order to determine the frequency of twin types for each locality and the frequency of right- and left-handed quartz crystals. Interest in this problem arose more from the geological implications than from the purely mineralogical aspects.

The writer is indebted to the late Arthur P. Honess for an introduction to the etch method and for encouragement in this study. Thanks are extended to several former associates for gifts of certain crystals and for

¹ Published by permission of the Director, U. S. Geological Survey.

² The term low-quartz refers, in this paper, to low-temperature quartz, that modification often called alpha and occasionally called beta which is stable below 573° C.

opportunities to discuss the problem. C. Wroe Wolfe kindly loaned his translation of Friedel's *Leçons de Cristallographie* and Siemon Muller certain Russian translations. Appreciation is expressed to J. D. H. Donnay, D. M. Fraser, C. S. Hurlbut, Jr., Earl Ingerson, and R. B. Sosman for constructive criticism of the original manuscript, and to R. D. Butler for discussions about the phantom crystals. J. C. Wynn very kindly loaned his drawings of phantom crystals from Brazil.

There is a voluminous literature on quartz but it is beyond the scope of this paper to review all of it. Many of the references are concerned with descriptions and study of quartz twins and twinning, the nature of the twin boundaries, quartz etch figures, vicinal faces, relations of form and twinning to temperature of formation, as well as geology and occurrence. Among the many workers who prior to 1940 contributed to the study of quartz along these lines are Baumhauer, Bendrich, Bomer, Bond, Brauns, Des Cloiseaux, Drugman, Friedel, Gaudefroy, Gill, Goldschmidt, Heide, Hirschwald, Ichikawa, Kalb, Larsen, Leydolt, Martini, Meen, Meyer, Molengraaf, Mügge, Nacken, Niggli, Penfield, Rose, Sosman, Trommsdorf, Von Roth, Websky, Weiss, Wright, and Witteborg. Since 1940, because of the great war demand for quartz oscillator-plates in the radio industry, added impetus was given in the United States to the study of quartz and its twinning by the work of Armstrong, Bond, Frondel, Gordon, Hurlbut, Parrish, Stoiber, Willard, and others. No attempt will be made to cite all of the references; some are noted in recent papers by Frondel, Parrish, Hurlbut, Gordon and others.³

Heide (1928) tabulates data for twenty-eight twin halves of Japanese twins from Saubach giving three with no twinning, fifteen twinned after the Dauphiné law, of which seven were left-handed and eight were right-handed, two after the Brazil law and eight after the Dauphiné-Brazil law. Trommsdorf (1937) examined 4,483 crystals from Villa Cristallina near Tres Capone, Brazil, and reported that 0.91 per cent were twinned according to the Brazil law. He also found that about half of those examined were right-handed and half were left-handed. His results are markedly at variance with those of Hurlbut (1946) for Brazilian quartz.

Thompson (1937) used the positions and striae on the s $\{11\bar{2}1\}$ and x $\{51\bar{6}1\}$ faces to determine handedness of 52 crystals from ten localities. He found that 24 were right-handed, thirteen were left-handed, and thirteen could not be identified. One Dauphiné twin and one Brazil twin

³ Symposium on quartz oscillator-plates, *Am. Mineral.*, **30**, 205-468, nos. 5 and 6 (1945); also other numbers of the *Am. Mineral.*; see also *Bell System Tech. Jour.*; reports and information circulars from the Office of the Chief Signal Officer, War Department; bulletins of the Fort Monmouth (Long Branch) Crystal Laboratories.

were found. However, Thompson had too few crystals for his data to be of statistical value. His method, while of interest to the mineral collector, is inadequate for a frequency study since only a small proportion of all quartz crystals have the *s* and *x* faces developed. Furthermore, in many cases it is not possible to determine the presence or absence of twinning from the development of these faces.

Saparova (1938) reported that, of thirty crystals from Wermsdorf, nineteen were twinned; eighteen according to the Dauphiné law and one according to the Brazil law.

Hurlbut (1946) gives some excellent data on the volume percentages of Dauphiné and Brazil twinning in quartz crystals from thirteen localities in Brazil, two in Guatemala, and one in Colombia. His article is based on research to determine which localities would yield the best grade of oscillator-plate quartz. Hurlbut examined 52,000 wafers cut from 3,015 crystals and thus gives a quantitative viewpoint not ordinarily obtainable by those outside the quartz industry. Since he did not report the frequencies of twin types or twinned and untwinned crystals, his data cannot be directly compared with those presented below but there seem to be some relationships. Hurlbut's data (p. 449, Table 3) shows differences in the volume percentages of twinning with greater differences among Brazilian, Colombian, and Guatemalan localities than among just Brazilian localities. This is brought out more strikingly by the yield of oscillator-plate blanks per pound than by the percentages of twinning, although, as Hurlbut points out, it is unfair in generalizing to say that Colombian and Guatemalan quartz are of lower grade (and thus in one sense more strongly twinned) than Brazilian quartz because of the limited quantities studied from the former localities.

There is also quantitative information on high-quartz crystals. One of the more informative studies is Mügge's (1892) on pyrogenic or rock-forming quartz including a number of euhedral high-quartz crystals from porphyries.

QUARTZ ETCH FIGURES

Excellent discussions of etch figures of quartz are given by Leydolt, Mügge, Ichikawa, Nacken, Gill, Meyer, Penfield, and Bond. Honess (1927) has discussed the entire subject of etching very thoroughly.

It is relatively easy to distinguish between right- and left-handed quartz by the use of etch figures (Meyer and Penfield, 1889) and, furthermore, the etch figures for all faces of one form etched with the same solvent are quite distinctive from those of other forms. The fact that different solvents develop different etch figures on the same face is of no significance here.

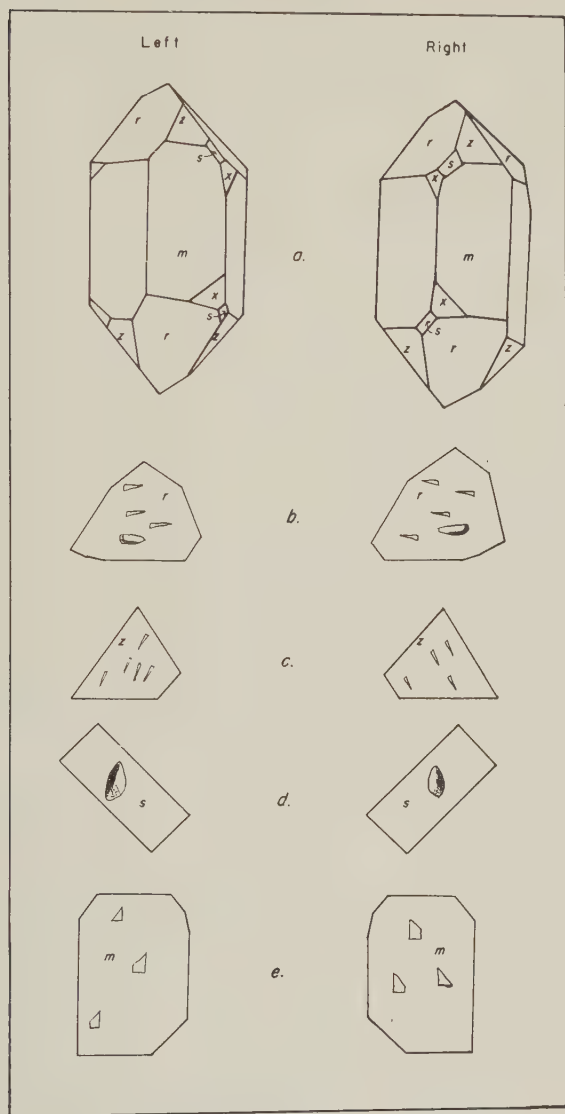


FIG. 1

Quartz can be etched by several solvents. Hydrofluoric acid has been the most widely used, although the quartz industry now uses a water solution of ammonium bifluoride (Parrish and Gordon, 1945) for safety reasons. Hydrofluoric acid was used in the present study. The etch figures produced by hydrofluoric acid on the rhombohedral faces r $\{10\bar{1}1\}$ and

z $\{01\bar{1}1\}$ are more or less triangular pits, the exact size and shape depending in part on the maturity of the pit (Honess, 1927, p. 32). The typical pits on the m $\{10\bar{1}0\}$ face are trapezoids. Etch figures produced by hydrofluoric acid on the r , z , m , and s faces of quartz are shown schematically in Fig. 1.

QUARTZ TWIN LAWS

There are six known twin laws for low-quartz (Friedel, 1926), namely, Dauphiné, Brazil, Japanese, Esterel, Sardinian, and Breithaupt. In addition, there is a complex type of twinning which is a combination of the Dauphiné and Brazil laws and has been variously called Liebisch twinning, combined twinning, combined optical twinning, combined Dauphiné-Brazil twinning, and Dauphiné-Brazil twinning. Dauphiné, Brazil, and Dauphiné-Brazil twins are penetration twins and are the most common types. Although they are the only twin laws considered in this study, a summary of all the known twin laws of quartz is included.

SUMMARY OF TWIN LAWS OF QUARTZ

Name	Twin		Composition plane	Remarks
	Axis	Plane		
Dauphiné	[0001]		irregular (10 $\bar{1}$ 0)	penetration twin; intergrowth of two right- or two left-handed individuals; rotation effect; common
Brazil		(11 $\bar{2}$ 0)	irregular (11 $\bar{2}$ 0)	penetration twin; intergrowth of a right- and a left-handed individual; reflection effect; common
Dauphiné-Brazil. Combined or Liebisch	(0001) and (11 $\bar{2}$ 0)		irregular	complex penetration twin; intergrowth of a right- and a left-handed individual; rotation and reflection effect; common
Japanese		variable ¹	(11 $\bar{2}$ 2)	contact twin; rare
Esterel		(10 $\bar{1}$ 1)	(10 $\bar{1}$ 1)	contact twin; rare
Sardinian		(10 $\bar{1}$ 2)	(10 $\bar{1}$ 2)	contact twin; rare
Breithaupt		(11 $\bar{2}$ 1)	(11 $\bar{2}$ 1)	contact twin; rare

¹ Heide (1928) considers four "laws" for Japanese twins of which the common designation (11 $\bar{2}$ 2) is one "law."

Recognition of penetration twins is largely a matter of etching and observing the type and arrangement of the etch figures (Fig. 2).

It is generally accepted that untwinned quartz is relatively uncommon

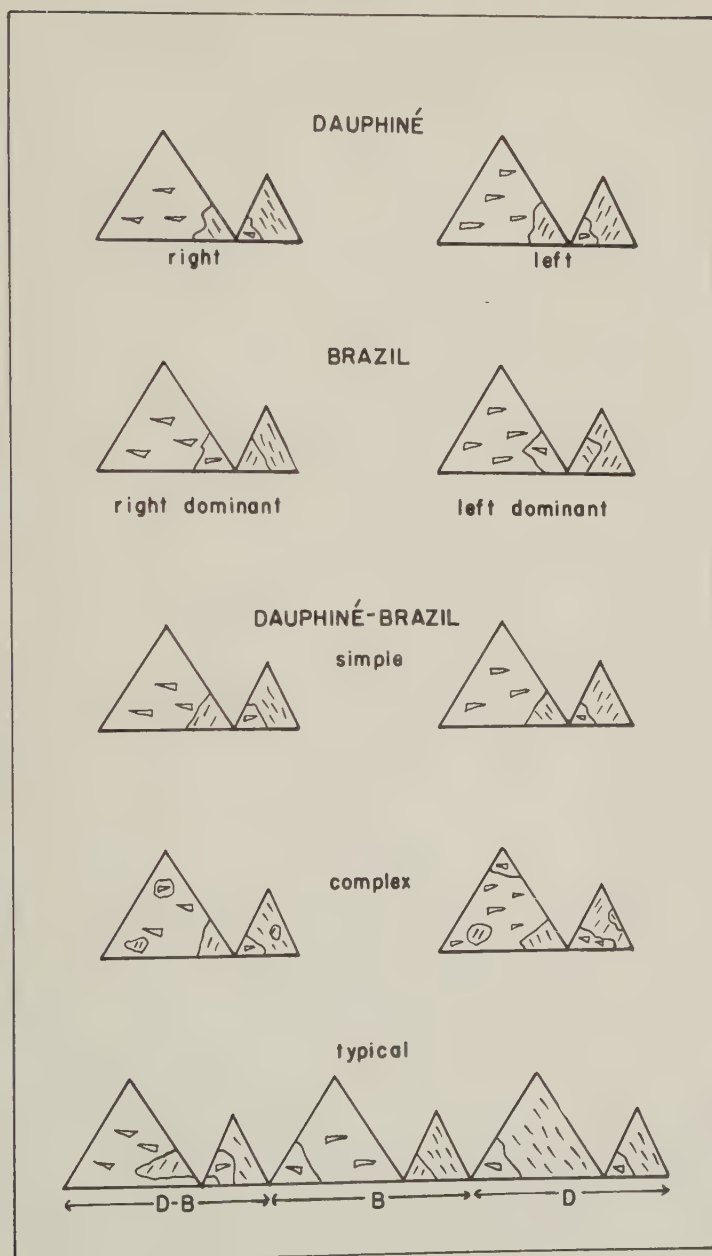


FIG. 2

and that most crystals are twinned according to the Dauphiné law and the Brazil law (Booth and Sayers, 1939; Gordon, 1945; and others). Booth and Sayers also indicate that Dauphiné-Brazil ("combined") twinning is very common.

In Dauphiné twinning, the $r \{10\bar{1}1\}$ and $z \{01\bar{1}1\}$ faces become coincident as if there were a 180° (or 60°) rotation of one part with respect to another about the c axis with the intergrowth of two right- or two left-handed individuals. This is electrical or orientational twinning. The boundaries between twin parts are irregular. Typical etch-figure patterns on the rhombohedral faces of Dauphiné twinned crystals are shown in Fig. 2.

Brazil twinning, also known as chiral or optical twinning, is the result of an intergrowth of a right- and a left-handed individual as if there had been a reflection across a second order prism. Thus a right $r \{10\bar{1}1\}$ face becomes coincident with a left $r \{10\bar{1}1\}$ face. Brazil twin boundaries are more regular than Dauphiné and in many cases are parallel to crystallographic directions. Characteristic Brazil twin boundaries and etch-figure patterns on the rhombohedral faces are shown in Fig. 2.

Internal twin boundaries of Dauphiné and Brazil twins in sections through the crystals are well illustrated and described by many workers; in recent years by Frondel (1945), Gordon (1945), Johnston and Butler (1946), Parrish and Gordon (1945), Willard (1944) and others.

The Dauphiné-Brazil twin has been described for many years but does not seem to have acquired a name until recently. Leydolt (1855, pl. 4) gives an excellent illustration of this type of twinning in a basal section. Liebis (1896) mentions it as one possible type of twin but applies no name. Lewis (1899) describes it as a possible composite crystal ("lævo-dextrogyral twins β ") and refers to amethyst crystals which supposedly show it. This complex twinning is pointed out in both editions of Weiss, *Mineralogy* (1902, 1929) and by Klockman (1923). Heide (1928) refers to Liebis's description and shows the symmetry of the twinned crystals schematically with etch-figure patterns. Heide's discussion is one of the most complete. Gaudefroy (1933) also recognized this type of twinning. No mention of twinning of this type is made in Hintze's *Handbuch*, in the 6th Edition of Dana's *System of Mineralogy* (1892), in Zirkel's *Elemente der Mineralogie* (1897), nor in Tutton's *Crystallography*, (1922).

The first name applied to this twinning was apparently given by Ivanov and Shafranovsky (1938) who illustrate types of twinned crystals which they refer to as simple and complex Liebis twins. Booth and Sayers (1939) describe and figure this same type of twinning but suggested the name "combined optical twinning." Willard (1944) also describes and

figures such twinning and calls it "combined twinning." Thomas (1945) suggested "combined twinning" as a shorter form of "combined optical twinning." Gordon (1945) and Frondel (1945) have also used the term "combined twinning" as have a few others. According to the illustration of Ivanov and Shafranovsky (1938), a simple Liebischtwin is a rigidly defined combination of both Dauphiné and Brazil twin-law effects in such a way that there is first an apparent rotation about the c axis (Dauphiné effect) and then there is an apparent reflection across a second order prism face (Brazil law effect). Thus in this simple twin a *right r* and a *left z* face become coincident (see Fig. 2) rather than a *right r* and a *left r* as in a Brazil twin or a *right r* and a *right z* as in a Dauphiné twin. Descriptions and figures by Heide (1928) and the comments of others agree in principle with the above.

This combination of the Dauphiné and Brazil laws is perhaps analogous to the complex albite-Carlsbad twin in the triclinic feldspars. There is, however, one difference. Because quartz is enantiomorphous, the twinning action cannot be performed by a single operation as it can for the albite-Carlsbad twin. In the albite-Carlsbad twin the simplest form has only two parts (1 and 2' of Winchell, 1933); part 1 is in the original position and part 2' is in a position that can be obtained by two rotations, one corresponding to the albite law and one to the Carlsbad law. Similarly in the simple Dauphiné-Brazil twin there are two parts, one in the original position and the second obtained by a rotation combined with a reflection. Such dual Dauphiné-Brazil twins are uncommon in quartz. In most crystals twinned according to the complex Dauphiné-Brazil law, as observed in the present study, there are many parts so that any one part will have a Dauphiné twin relation to a second, a Brazil twin relation to a third, a Dauphiné-Brazil relation to a fourth.

Typical Dauphiné-Brazil twin-law etch-figure patterns on the rhombohedral faces are shown in Fig. 2, which illustrates possible etch-figure patterns on rhombohedral faces where the Dauphiné effect appears on one face, the Brazil effect on a second face, and the Liebischtwin effect on a third face. Some of these variations have been noted.

On the basis of date of publication, Ivanov and Shafranovsky's name "Liebischtwin" should have precedence over the others. From the standpoint of usage, the term "combined twinning" seems well established and understood in the quartz oscillator-plate industry. Despite precedence and usage, it is suggested that this type of twinning in quartz should be called "Dauphiné-Brazil twinning" just as the complex feldspar twin laws are named after their combinations. As crystals showing only a simple Dauphiné-Brazil twin pattern or "Liebischtwin" effect are rare, it may be desirable to drop the term "Liebischtwin."

PROCEDURE

All of the crystals used in this study possessed the trigonal symmetry of low-quartz. Groups of crystals were obtained from each locality without any selective sampling other than the requirement that each crystal have its terminal faces completely developed. The crystals were etched with hydrofluoric acid until the etch figures were sufficiently mature for recognition of outline and orientation. No attempt was made to control the time of etching or the concentration of the acid. After etching, the crystals were examined under a binocular microscope in reflected light and classified according to the twin laws indicated by the etch figure patterns (see Fig. 2).

All observations were confined to the rhombohedral faces of crystals except in the case of those from Herkimer County, N. Y. This was necessary in most cases because of the lack of development of prism faces or because the prism faces were too striated or otherwise roughened for etching. In some cases, particularly with the Arkansas crystals, it was possible to trace twin boundaries from the rhombohedral faces to the adjacent prism faces.

RESULTS AND DESCRIPTION OF MATERIAL

A total of 1,179 crystals from six widely separated geographic locations and distinct geologic occurrences were examined. The statistical data are presented in Table 2. No distinction is made in the table between simple and complex Dauphiné-Brazil twinning. In classifying Brazil and Dauphiné-Brazil twins there is always the problem of whether they should be placed with right-handed or left-handed crystals. Only in a few instances was any difficulty experienced in determining which type of quartz was dominant in a crystal. It is generally obvious from visual inspection that one or the other is dominant.

As others have pointed out, right- and left-handed quartz occur in about equal proportions in "untwinned" crystals as well as in Dauphiné twins. Brazil twins and Dauphiné-Brazil twins, with respect to the dominant handedness in each crystal, also show right- and left-handed quartz in about equal proportions.

The relative frequency of untwinned and twinned crystals varies from place to place, and the relative frequency of the interpenetration twin laws also varies considerably. Accordingly, there is a determinable ratio between twin types for individual localities. For the total number of crystals studied, Dauphiné-Brazil twins are slightly more common than Dauphiné twins. Brazil twins are relatively uncommon. However, in the breakdown by localities, the relative frequencies, at any one oc-

currence show more variation. Actually, Dauphiné twins are more abundant in four of the six occurrences (Arkansas, Utah, Maryland, Alaska) than Dauphiné-Brazil twins. Brazil twins are more abundant than Dauphiné twins and nearly equal to Dauphiné-Brazil twins at one locality (New York). Dauphiné twins are present at all localities but Brazil twins are lacking at three localities (Pennsylvania, Maryland, Alaska). Dauphiné-Brazil twins were not recognized at two localities (Utah and Maryland).

An apparent correlation was noted, particularly for the Arkansas crystals, between the frequency and amount of twinning and the shape of the crystal. The more tapered crystals (candle-like habit) tend to show less twinning. Hurlbut (1946) shows this quantitatively in graphic form for Brazilian quartz. There is also a suggestion that individual crystals bearing the less common faces s $\{11\bar{2}2\}$ and x $\{51\bar{6}1\}$ are less strongly twinned than crystals carrying only the rhombohedral faces.

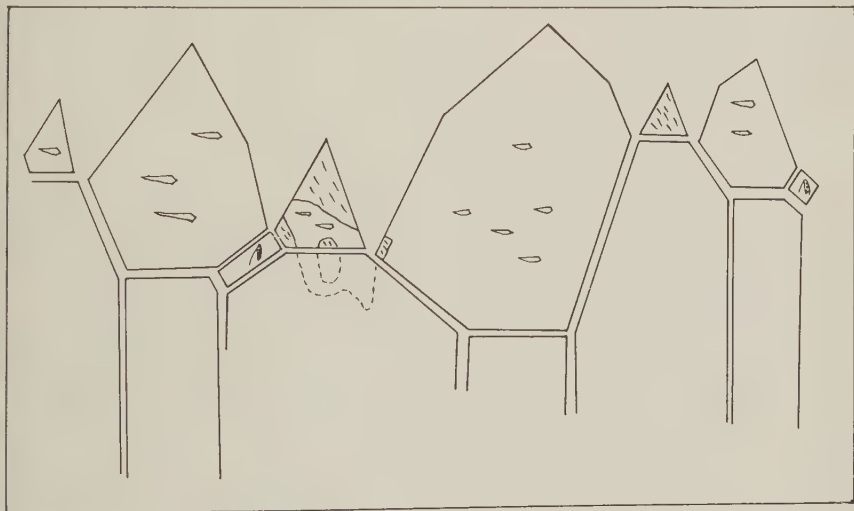


FIG. 3

Arkansas crystals—Quartz crystals from Arkansas are well known and their occurrence and geology have been well described by Miser (1943) and Engel (1946). The material used in this study came from the Fisher mines about seven miles southeast of Mount Ida, Montgomery County, near the southwest end of the main district in western Arkansas (Engel Fig. 1, 1946). The crystals are singly terminated and range from 3/8 inch to one inch in diameter and one inch to two inches in length. They belong to Engel's simple type (p. 606, 1946). Most of them have clear

terminations with milky lower portions. None of the crystals reported in Table 1 showed any *s* or *x* faces. Typical twin boundaries on the rhombohedral faces of the Arkansas crystals are shown in Fig. 3.

In addition to the Arkansas crystals reported in the table, a second group of 160 singly terminated crystals representing a number of Arkansas localities were also examined. It is a pleasure to thank Mr. Hugh D. Miser, U. S. Geological Survey, for the gift of these crystals. The crystals in this group are distinctive in that they all show the development of *at least* one $x \{51\bar{6}1\}$ and one $s \{11\bar{2}1\}$ face. The data for these crystals are not included in Table 2 because they do not represent one place but instead are samples from many localities. The frequencies of the twin laws are given in Table 1.

TABLE 1. FREQUENCY OF TWIN LAWS IN ARKANSAS QUARTZ CRYSTALS

	<i>Rnt</i> *	<i>Lnt</i>	<i>Rd</i>	<i>Ld</i>	<i>Rb</i>	<i>Lb</i>	<i>Rdb</i>	<i>Ldb</i>
Number	39	46	22	16	13	15	5	4
Per Cent	24	29	15	10	8	9	3	3-
(rounded off)								
Ratio (d:b:db)				10:7.5:3				

* R=right; L=left; nt=no twinning; d=Dauphiné; b=Brazil; db=Dauphiné-Brazil.

This assemblage of crystals shows a greater proportion of untwinned crystals than do those lacking the *x* and *s* faces. This difference is largely at the expense of the Dauphiné twins. There is also a slight decrease in the total frequency of intergrowths of right- and left-handed individuals with the Dauphiné-Brazil twinning giving way to Brazil twinning.

Pennsylvania crystals.—There are a number of localities in Pennsylvania and Maryland where quartz crystals occur in soil overlying limestones. Presumably they are residual from the weathering of the limestones. The material described here came from a field underlain by Trenton limestone (Butts and Moore, 1936) just east of Lemont, Centre County. Quartz crystals were found also in the limestone and in calcite veins cutting the limestone. None of them, however, was as large as the largest crystals found in the soil.

TABLE 2. FREQUENCY OF TWIN LAWS IN QUARTZ CRYSTALS

<i>Locality</i>	<i>Rnt</i> *	<i>Lnt</i>	<i>Rd</i>	<i>Ld</i>	<i>Rb</i>	<i>Lb</i>	<i>Rdb</i>	<i>Ldb</i>	<i>Total</i>
Arkansas	12	12	99	87	12	8	30	35	295
%	4.1	4.1	33.6	29.5	4.1	2.7	10.2	11.9	
Pennsylvania ¹	4	3	16	12	0	0	159	153	347
%	1.1	.8	4.6	3.4	0	0	45.8	44.1	

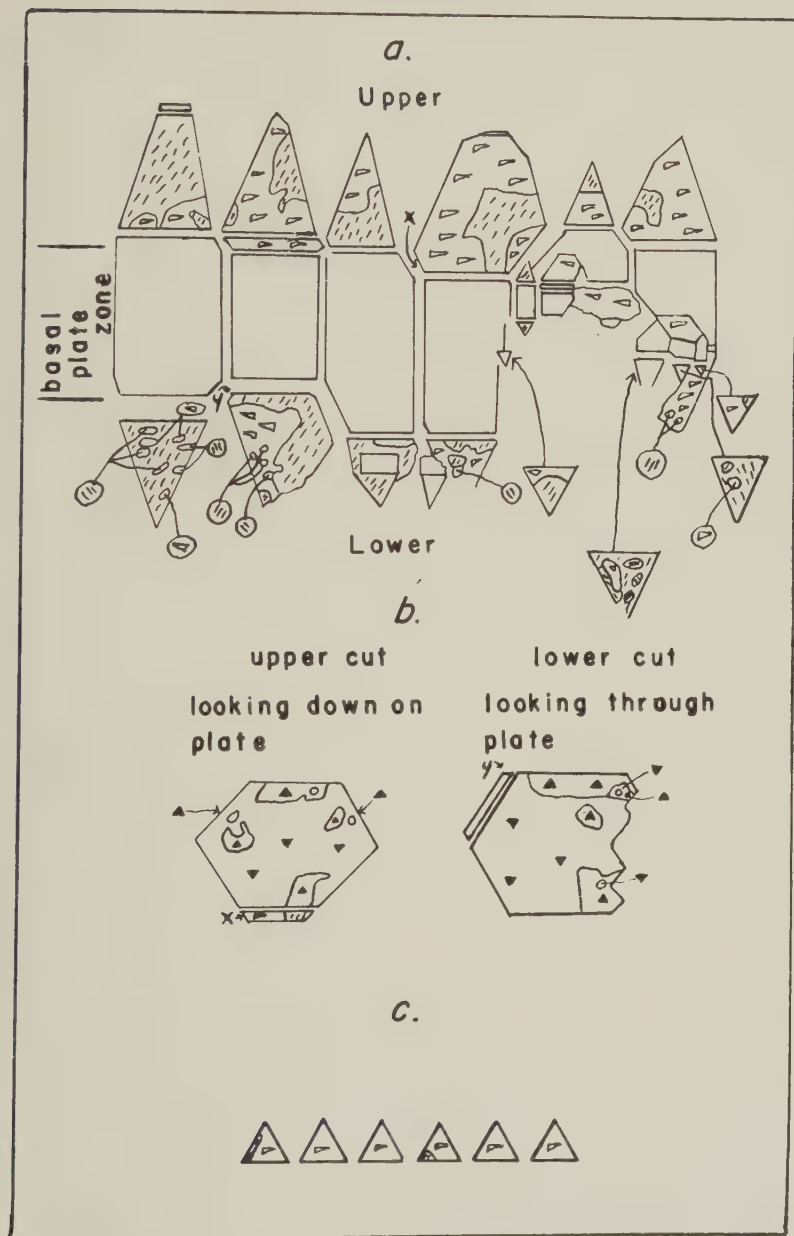


FIG. 4

Tintic, Utah	69	65	16	15	3	0	0	0	168
%	41.1	38.8	9.5	8.9	1.8	0	0	0	
Herkimer Co., N.Y. ²	14	13	1	2	3	2	3	6	44
%	31.8	29.5	2.3	4.5	6.8	4.5	6.8	13.6	
Maryland	9	12	7	10	0	0	0	0	38
%	23.7	31.6	18.4	26.3	0	0	0	0	
Alaska	0	0	30	40	0	0	21	20	111
%	0	0	27	36.1	0	0	18.8	18	

Total right-handed or right-handed dominant 518 or 51.6%

Total left-handed or left-handed dominant 485 or 48.4%

* R=right; L=left; nt=no twinning; d=Dauphiné; b=Brazil; db=Dauphiné-Brazil.

¹ 12 additional crystals showed Rb at one end and Lb at the other.

3 additional crystals showed Rnt at one end and Lnt at the other end.

² 1 additional crystal showed Rnt at one end and Lnt at the other end.

All of the crystals studied are doubly terminated with roughened and striated prism faces. Inclusions of dark materials, cavities, irregular growth habits and internal flaws are common to all crystals. They are not clear like the Herkimer County, New York, crystals. The crystals examined are one-quarter inch to one inch in diameter and one-half inch to one and one-half inches long. Typical twin boundaries on the rhombohedral faces are shown in Fig. 4a. Figure 4b shows internal twinned parts.

Utah crystals—The crystals were taken from a small drusy specimen collected in the Tintic district. Barite crystals were associated with the quartz crystals. The latter are small singly terminated crystals with a diameter of about one-eighth inch and a length of about three-eighth inch.

New York crystals—The material used in this study is typical of the well-known Herkimer County, New York, product. The crystals range from one-quarter inch to three-quarters inch in diameter and one-half inch to one and one-half inches in length. On all of these crystals it was possible to trace the external twin boundaries on the prism faces. The exact locality is unknown, but all are from the same general location.

Maryland crystals—These crystals came from a small quartz vein in the Wissahickon formation near Baltimore. The crystals are about the same size as the Tintic, Utah, material and are singly terminated with only the rhombohedral faces developed.

Alaska crystals—The Alaska crystals are from Glacier Basin, near Wrangell, Alaska. They occurred as drusy deposits with a comb-like structure in vugs or along the walls of quartz-fluorite breccia veins cutting a series of metamorphic rocks in the Coast Ranges. The geology and

veins are described by Gault, Rossman and Flint (1944a & b). The crystals are singly terminated with only the rhombohedral faces developed. The bases of the terminations are one-eighth inch to one-half inch in diameter. Typical twin patterns are shown in Fig. 4c.

The etch figures on these crystals indicate an unusual development of the r $\{10\bar{1}1\}$ face over the z $\{01\bar{1}1\}$ face (see Fig. 4c). Although low-quartz crystals are commonly malformed during growth, the trigonal symmetry of quartz is generally revealed by the unequal areas of the r and z faces, the z faces being much smaller. In these Alaskan crystals all six terminal rhombohedral faces are commonly present and generally are also nearly equal in size. Etching, however, shows that practically all of the rhombohedral faces belong to the plus or r form. In most cases the z face, where present, is a small, narrow band along one edge or the base of a face; in many cases it could not be recognized at all by etch figures. This locality is the only one herein considered where there is such an extreme predominance of the r face over the z face.

No crystals were noted twinned only according to the Brazil law. In the crystals twinned according to the Dauphiné-Brazil complex law, the second enantiomorphous individual always made its appearance near the base of the rhombohedral faces and in practically all cases it was indicated by the coincidence of right- and left-handed r faces.

DISCUSSION

Some discussion of the procedure seems warranted to avoid criticism with regard to confining observations to the rhombohedral faces. It is obvious, of course, that where no prism faces were developed, no etch figures could be obtained for studying twin boundaries on the exterior of the crystals. Some twinning may have been overlooked by not studying the prism faces as thoroughly as the rhombohedral faces. However, further observations were made, where possible, on those crystals which showed no twinning on the rhombohedral faces to see if there were twin boundaries on the prism faces not extending to the rhombohedral faces. In some instances such boundaries were observed but not in enough cases to change noticeably the actual numbers of crystals and, even less, to change the ratios among twin types.

Another comment which may be made is that this study has dealt thus far only with the exterior of the crystal and no consideration has been given to the interior. An approach to this question of interior twinning was made by taking 20 Arkansas crystals which showed no twin boundaries on the rhombohedral faces, cutting a basal section from each one slightly below the base of the termination, and etching the basal sections. Of the 20 sections, 12 showed no twinning at all. The other 8

crystals showed quite small irregular patches of twinning which were restricted to the very edges of the crystals but were not always recognizable on the prism faces. Four of these eight crystals each carried one small twinned part near the center of the section. Because these did not appear on the rhombohedral faces, it is suggested that some twinned parts were wholly internal, i.e. entirely surrounded by other quartz. Heide (1928) also suggested that material appearing as untwinned quartz

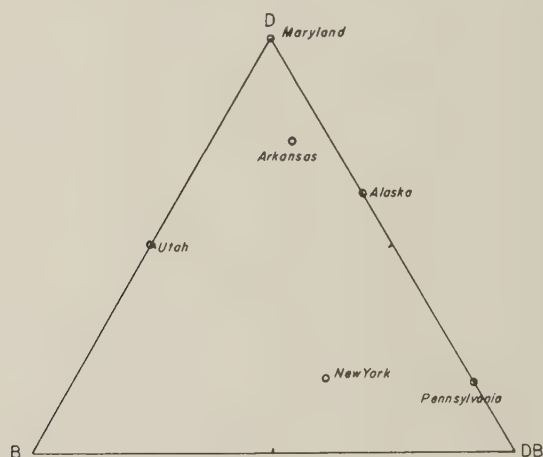


FIG. 5

in poorly developed crystals might actually be twinned elsewhere in the crystal. This suggestion is further substantiated by Hurlbut,⁴ who, from his extensive experience in the quartz industry, says it is quite possible and frequently happens that twinned parts are entirely enclosed by other quartz and do not appear on the exterior of the crystal. Hurlbut's work with so many thousands of wafers should be conclusive.

Of the 20 crystals mentioned above, 40 per cent of those tested showed twinned parts which were not recognized on the rhombohedral faces. Although this is a considerable percentage of the so-called untwinned crystals, actually the distribution of these twins did not change the ratio of twin types. Thus, if there is any hesitancy in accepting the untwinned group as truly untwinned crystals, it can be disregarded and only the ratios of twin types accepted. On this basis, the approximate ratios of twin types for each locality are given below as derived from the relative frequencies in Table 2 (see also Fig. 5).

⁴ Personal communication.

RATIOS OF TWIN TYPES

	<i>Dauphiné</i>		<i>Brazil</i>		<i>Dauphiné-Brazil</i>
Arkansas	10	:	1.1	:	2.2
Pennsylvania	10	:	0.6	:	110.0
Utah	10	:	1.0	:	0.0
New York	10	:	17.0	:	30.0
Maryland	10	:	0.0	:	0.0
Alaska	10	:	0.0	:	6.0

Practically, of course, the study of twin boundaries in quartz only at the surface of the crystals does not tell much about the extent of the twinned material within the crystal. Confining the observations to the rhombohedral faces limits this still more. However, it can be shown from the geometry of most of the crystals that the principal direction of growth was parallel to the c axis and probably on the rhombohedral faces. It is readily apparent that if, as a seed crystal grows, the rhomb faces are the areas of greatest deposition the crystal will become elongate parallel to the c axis. In order to produce broad short crystals the rate of growth on the prism faces must be greater than on the rhomb faces. One indication of direction of growth is phantom crystals. Johnston and Butler (1946) figure a number of phantom crystals from Brazil and state (p. 639):

The prismatic habit of quartz is reflected by the phantom relations—growth was usually pronounced along the c axis after formation of the phantom even though the center of gravity in the basal planes conspicuously shifted.

Their figures as well as other unpublished figures⁵ of phantom crystals from Brazil all show the rhomb faces as having a greater thickness of quartz in each phantom than do the corresponding prism faces.⁶

In a general way, similar conditions of growth are inferred for the crystals described herein, all of which have their long dimension parallel to the c axis. Therefore, observations on the rhombohedral faces of these crystals should reflect the frequency and nature of twinning at the places of greatest deposition, at least during the last stage of growth of the crystals. The groups of so-called untwinned crystals should now take on more significance because they would indicate there was no twinning developing at that time. Unless there were radical changes in conditions

⁵ The writer is indebted to Mr. J. C. Wynn for the opportunity to study a set of 100 unpublished drawings of phantom crystals from Brazil. Johnston's and Butler's (1946) illustrations of phantoms are from this set.

⁶ The problem of asymmetry of apices and direction of flow of solutions does not enter into this discussion (Newhouse, 1941; Bandy, 1942; Engel, 1946). The Brazilian crystals apparently have retained the asymmetry of the "seed" crystal of the phantoms throughout the growth of the phantoms.

of growth from early to late stages, the observations should perhaps be an indication of what would be found within the crystal. Even if there were radical changes from early to late stages, it seems reasonable to believe that they would have been in degree of controlling factors rather than in type. Where no twinning or only isolated patches of twinned quartz are exposed at the surface of the crystal, it does not seem probable that the interior of the crystal should show strong twinning with many parts.

Because internal twinned parts are not taken into account, these data are not rigidly quantitative but rather they express a relative frequency of and ratio between twin types. If the materials described herein were studied along the lines applied by Hurlbut (1946), there might be no groups of untwinned crystals but such groups according to the present classification might show only very small volume percentages of twinned quartz.

The ratios between twin types for each locality may be characteristic of different types of geologic occurrence. Frondel (1945) has stated that the relative development of Dauphiné and Brazil twinning varies widely as does the individual percentage of the twin types and that the type of occurrence seems to be a controlling factor in the relative development of twins. Hurlbut's (1946) data, although given as volume percentages, indicate a difference in the amount of twinning from place to place. As Hurlbut points out, the correlation between percentage of twinning and yield of oscillator blanks per pound is far from perfect, but study of his data shows the yield from Brazilian localities to fall within certain limits which are higher than the limits of the yield from other than Brazilian localities. The correlation of volume percentages of Dauphiné and Brazil twinned parts with locality is less obvious than for yield of blanks, but again all of the Brazilian localities fall within certain limits outside of which the volume percentages of the other localities lie.

There is also a suggestion, albeit weak, that for a group of localities of similar origin there may be upper and lower limits for the volume percentage of twinning as compared with other types of occurrences. Unfortunately, Hurlbut could not list specific localities for security reasons, and so it is not possible to compare his Brazilian localities with the four major quartz belts in Brazil (Stoiber, Tolman, and Butler, 1945). Possibly a closer correlation and narrower limits for each belt might be forthcoming. On the other hand, Campbell (1946) includes two of the quartz belts described by Stoiber in one type of geologic occurrence. It would appear that very broadly speaking all Brazilian localities are similar in origin and geologic occurrence and belong to a single genetic period (Kerr and Ericksen, 1942; Johnston and Butler, 1946, and

others). Where the frequencies of twin types for a number of localities fall within certain limits, these limits may be distinctive for deposits which have similar conditions of origin and geologic environment, but which are geographically distinct. Further study is needed to verify or refute this. Engel states (p. 608, 1946) that, although all correlation of occurrence and nature of optical twinning is speculative, it is known that the ratio of highly twinned to relatively untwinned quartz is fairly constant for a single deposit or group of related deposits. It varies considerably between localities in dissimilar country rock.

The problem of the geological significance of variations of the frequency of twins and of the ratios between twin types is of considerable interest, but many additional observations and some experimental data are needed before any satisfactory conclusions can be drawn. The frequencies of twins and the ratios between twin types seem to be a reflection of the mode of occurrence which will require the consideration of many environmental factors, in fact, more than can be resolved at present. Thus it is not possible to relate twin ratios and frequencies at this time to geological occurrence. Factors which probably exert an important influence are temperature, concentration, impurities, nature of the wall rock, rate of cooling and pressure.

Temperature studies have been made to (1) determine whether the quartz crystallized as the high or low form (Mügge, 1907, 1921; Wright and Larsen, 1909) and (2) to distinguish temperature stages in types of low-quartz crystals (Maucher, 1914; Mügge, 1921; Kalb, 1933, 1935; Virovlyanski, 1938*a*, 1938*b*). The criteria of the nature of twin boundaries and their patterns for determining high- or low-quartz crystallization are becoming less and less applicable as a result of recent work (Fron del, 1945; Armstrong, 1946). Virovlyanski (1938*a* and *b*) and Engel (1946) found Kalb's scheme (based on vicinal faces) unreliable.

The influence of impurities on twinning in quartz has been pointed out recently by Zinserling (1941), Johnston and Butler (1946), and Armstrong (1946). Two types of impurities are important; those incorporated in the crystals during its growth and those which settled out of suspension onto earlier growth planes.

SUMMARY AND CONCLUSIONS

There is a great need for further observation and experimentation before the geological significance of the frequency of twins and the ratios between twin types in quartz can be fully understood. Temperature measurements on inclusions similar to those reported by Newhouse (1933), Ingerson (1947), and Twenhofel (1947) would be very valuable. Further studies along that line are in progress for the crystals described

herein. Study of growth patterns and twinning in the various parts of phantom crystals may contribute much to the problem.

There are, however, several well established points with respect to quartz twinning which can serve as a basis for future work.

1. Twinned quartz crystals are much more common than untwinned crystals—in fact, untwinned crystals may be considered a rarity.
2. Penetration twins are the most common type. Contact twins are rare.
3. Crystals twinned according to both the Dauphiné and the Brazil laws should be called “Dauphiné-Brazil” twins rather than “combined” twins.
4. Of the three types of penetration twins, those twinned according to the Dauphiné and Dauphiné-Brazil laws are as a rule more abundant than Brazil twins, particularly the Dauphiné-Brazil. The excess is sometimes slight, sometimes overwhelming. The common occurrence of Dauphiné-Brazil twins has not been fully recognized.
5. Right- and left-handed quartz crystals are found to occur in equal proportions when a sufficient quantity of material is examined. Even in Brazil and Dauphiné-Brazil twins, though one handedness is dominant over the other in each crystal, those with right dominant are equal to those with left dominant.
6. Dauphiné twin boundaries are irregular, whereas Brazil boundaries are more likely to be parallel to crystallographic planes.
7. Crystals on which the less common faces of general forms are developed show less twinning than other crystals from the same locality.
8. The relative frequency of the twin types varies considerably from locality to locality. These variations must surely be a reflection of the conditions of growth and geologic environment.

REFERENCES

1. ARMSTRONG, ELIZABETH, (1946), Relation between secondary Dauphiné twinning and irradiation-coloring in quartz: *Am. Mineral.*, **31**, 456–462.
2. BANDY, MARK C. (1942), Direction of flow of mineralizing solutions: *Ec. Geol.*, **37**, 330–333.
3. BOOTH, C. F., AND SAYERS, C. F., (1939), The production of quartz resonators for the London-Birmingham coaxial cable system: *P. O. Elec. Eng. Jour.*, **31**, 245–253.
4. BUTTS, CHARLES, AND MOORE, ELWOOD S., (1936), Geology and mineral resources of the Bellefonte quadrangle, Pa.: *U. S. Geol. Surv., Bull.* **855**.
5. CAMPBELL, D. F., (1946), Quartz crystal deposits in the state of Goiaz, Brazil: *Ec. Geol.*, **41**, 773–800.
6. ENGEL, A. E. J., (1946), The quartz crystals of western Arkansas: *Ec. Geol.*, **41**, 598–619.
7. FRIEDEL, GEORGES, (1926), *Leçons de cristallographie*: Berger-Levrault, Paris, 602 pp.
8. FRONDEL, CLIFFORD, (1945), Secondary Dauphiné twinning in quartz: *Am. Mineral.*, **30**, 447–461.
9. GAULT, H. R., (1944a), Zinc deposits of Groundhog Basin, Wrangell district, southeastern, Alaska; mineographed report, *U. S. Geol. Surv.*, (March).
10. ———, ROSSMAN, D. L., AND FLINT, G. M., JR., (1944b), Geology and mineral deposits of Glacier Basin and vicinity, Wrangell district, southeastern, Alaska: mimeographed report, *U. S. Geol. Surv.*, (May).
11. GAUDEFROY, M. C. (1933), Sur les groupements de cristaux de quartz à axes parallèles: *Bull. Soc. Min. (France)*, **56**, 5–63.
12. GORDON, S. G., (1945), The inspection and grading of quartz: *Am. Mineral.*, **30**, 269–290.

13. HEIDE, F., (1928), Die Japaner Zwillinge des Quarzes und ihr Auftreten in Quarzporphyr vom Saubach i. V.: *Zeit. Krist.*, **66**, 239-282.
14. HONESS, A. P., (1927), The nature, origin, and interpretation of the etch figure: John Wiley and Sons, New York.
15. HURLBUT, CORNELIUS S., JR., (1946), Influence of twinning on the usability of quartz: *Am. Mineral.*, **31**, 443-455.
16. INGERSON, EARL, (1947), Liquid inclusions in geologic thermometry, *Am. Mineral.*, **32**, 375-388.
17. IVANOV, N. A., AND SHAFRANOVSKY, I. I., (1938), Outward indications of the important twins of quartz: *Soc. Russe Miner., Mem.* **67**, Iv. 3, 435-445.
18. JOHNSTON, W. D., JR., AND BUTLER, R. D., (1946), Quartz crystal in Brazil: *Bull. Geol. Soc. Am.*, **57**, 601-650.
19. KALB, G., (1933, 1935), Beiträge zur Kristallmorphologie des Quarzes: *Zeit. Krist.* **86**, 439-465; **90**, 163-186.
20. KERR, P. F., AND ERICHSEN, A. I., (1943), Origin of the quartz deposits at Fazenda Pacú, Brazil: *Am. Mineral.*, **27**, 487-499.
21. KLOCKMAN, F., (1923), Lehrbuch der Mineralogie: Stuttgart.
22. LEWIS, W. J., (1899), A Treatise on Crystallography: Cambridge Univ. Press.
23. LEYDOLT, FRANZ, (1855), Ueber eine neue Methode, die Structur und Zusammensetzung der Krystalle zu untersuchen, mit besonderer Berücksichtigung der Varietäten des rhomboedrischer Quarzes: *Akad. d. Wiss. Wien*, **15**, 59-82.
24. LIEBISCH, THEODOR, (1896), Grundr. phys. Kristallographie; Leipzig.
25. MAUCHER, W., (1914), Die Bildungsreihe der Mineralien als Unterlage für die Einteilung der Erzlagerstätten: Freiberg i. S.
26. MEYER, O., AND PENFIELD, S. L., (1889), Results obtained by etching a sphere and crystals of quartz with hydrofluoric acid: *Trans. Conn. Acad.*, **8**, 158-165.
27. MIERS, H. A., (1902, 1929), Mineralogy; first edition, London; second edition, London.
28. MISER, HUGH D., (1943), Quartz veins in the Ouachita mountains of Arkansas and Oklahoma: *Ec. Geol.*, **38**, 91-118.
29. MUGGE, O., (1892), Ueber den Kristallbau der pyrogenen quarz: *Neues Jahrb. f. M., P.*, **I**, 1-14.
30. ———, (1907), Ueber die Zustand sänderung des Quarzes bei 570°: *Neues Jahrb. f. M., P., P.*, Festband, 181-196.
31. ———, (1921), Quarz als geologisches Thermometer und die Bedeutung der Zusammensetzungsflächen von Kristallzwillingen; *Centrl. Min., Geol.*, 609-615; 641-648.
32. NEWHOUSE, W. H., (1933), The temperature of formation of the Mississippi Valley lead-zinc deposits: *Ec. Geol.*, **28**, 744-750.
33. ———, (1941), The direction of flow of mineralizing solutions: *Ec. Geol.*, **36**, 612-630.
34. PARRISH, WILLIAM, AND GORDON, S. G., (1945), Orientation techniques for the manufacture of quartz oscillator-plates: *Am. Mineral.*, **30**, 296-325.
35. SAPAROVA, JISKRA, (1938), Quartz from Wernsdorff in northern Moravia: *Casopis Zemskeho Musea v. Brně*, **30**, 32 pp.
36. STOIBER, RICHARD E., TOLMAN, CARL, AND BUTLER, ROBERT D., (1945), Geology of quartz crystal deposits; *Am. Mineral.*, **30**, 245-269.
37. THOMAS, L. A., (1945), Terminology of interpenetrating twins in low-quartz: *Nature*, **155**, 424, (April 7).
38. THOMPSON, M. R., (1937), How to tell right-handed from left-handed quartz crystals: *Rocks and Minerals*, **12**, 38-43.
39. TROMMSDORF, WOLF, (1937), Das Verhältnis der Anzahl der Linksquarze zu der Rechtsquarze in einer grösseren Menge von Quarzkristallen: *Neues. Jahrb. f. M., P., P.*, **B. B.**, Abt. **A**, 464-495.

40. TUTTON, A. E. H., (1922), Crystallography and Practical Crystal Measurement, vol. 1, Form and Structure, MacMillan.
41. TWENHOFEL, W. S., (1947), The temperature of crystallization of a fluorite crystal from Luna County, New Mexico: *Ec. Geol.*, **42**, 78-82.
42. VIROVLYANSKY, G. M., (1938a), Quartz as a geologic thermometer: *Soc. Russe Miner., Mem.*, **67**, lv. 2, 236-246.
43. ———, (1938b), On the question about the mirogenetic importance of vicinal figures on the edges of quartz: *Soc. Russe Miner., Mem.*, **67**, lv. 2, 446-450.
44. WILLARD, G. W., (1944), Use of the etch technique for determining orientation and twinning in quartz crystals: *Bell Sys. Tech. Jour.*, **23**, 11-51.
45. WINCHELL, A. N., (1933), Elements of Optical Mineralogy, part II, John Wiley and Sons, New York.
46. WRIGHT, F. E., AND LARSEN, E. S., (1909), Quartz as a geologic thermometer: *Am. Jour. Sci.*, 4th ser., **27**, 421-447.
47. ZINSERLING, E. V., (1941), Quartz twinning control under alpha-beta inversion; Quartz coloring as dependent on its twinning capacity under alpha-beta conversion; (and Laemmlein, G. G.) Conversion of a negative quartz rhombohedron into a positive one as a result of alpha-beta transformation: *Compte Rendu, Acad. Sci., U.S.S.R.*, **33**, 365, 368, 419.
48. ZIRKEL, F., (1897), Elemente der Mineralogie (Naumann), Leipzig.

THE UNIT CELL AND SPACE GROUP OF LINDGRENITE

WILLIAM H. BARNES,

National Research Council, Ottawa, Ontario, Canada.

ABSTRACT

The unit cell constants and the space group of lindgrenite, $2\text{CuMoO}_4 \cdot \text{Cu}(\text{OH})_2$, have been determined by the Buerger precession method with the following results: $a = 5.613 \text{ \AA}$, $b = 14.03 \text{ \AA}$, $c = 5.405 \text{ \AA}$, $\beta = 98^\circ 23'$; $a:b:c = 0.4001:1:0.3852$; $Z = 2$; calculated density $= 4.295 \text{ g./cc.}$; space group $P2_1/n$.

INTRODUCTION

Lindgrenite, $2\text{CuMoO}_4 \cdot \text{Cu}(\text{OH})_2$, was described by Professor Charles Palache in 1935 as monoclinic, $a:b:c = 0.5941:1:0.5124$, $\beta = 92^\circ 12'$, specific gravity $= 4.26$ (1). On the basis of b and c axis zero level Weissenberg photographs and three rotation photographs the dimensions of the unit cell were determined as $a = 8.45 \text{ \AA}$, $b = 14.03 \text{ \AA}$, $c = 7.04 \text{ \AA}$, $\beta = 92\frac{1}{2}^\circ$ and it was concluded that the most suitable structural axes were identical with the morphological axes.

The present investigation was undertaken to verify the unit cell constants and to determine the space group as a preliminary step in a complete structure study. The unit cell and space group results are being reported at this time partly because the improved and more extensive data furnished by the precession method has led to a change in the axes most suitable for describing the structural unit and partly because of a change in laboratories and attendant delay in intensity measurements and computations.

Crystals of lindgrenite were kindly supplied by Dr. Clifford Frondel from the same specimen which served for the original morphological study.

X-RAY DATA AND RESULTS

X-ray photographs of the zero and first two or three reciprocal lattice levels normal to the morphologically assigned a and b axes were taken with Professor M. J. Buerger's precession instrument (2). Both copper (nickel foil filter) and molybdenum (zirconium oxide filter) radiations were employed. Cone axis photographs were used as a check on the identity of the several levels photographed. The best of the zero level a and b axis photographs were measured with the instrument devised by Professor Buerger (3) for this purpose.

Typical precession photographs are reproduced in Figs. 1, 2, 3, 4. The central area of the plane nets characteristic of the zero, first and second

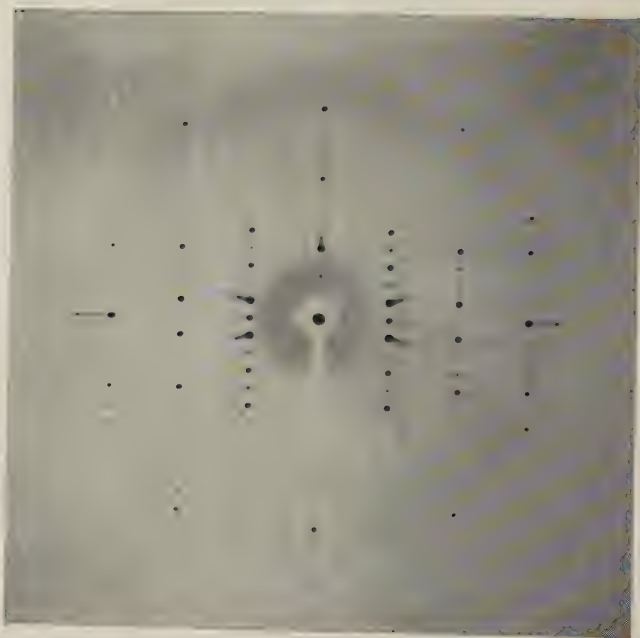


FIG. 1. Lindgrenite, a axis, zero level (Mo) (c^* horizontal)

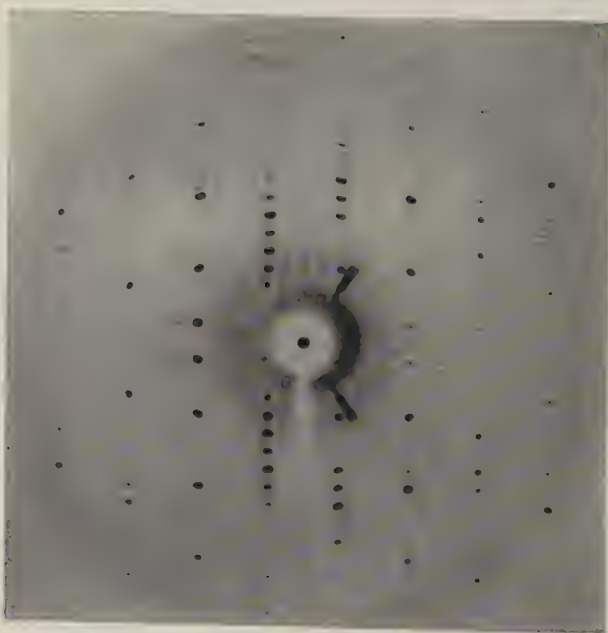


FIG. 2. Lindgrenite, a axis, first level (Mo) (c^* horizontal)



FIG. 3. Lindgrenite, b axis, zero level (Mo) (ψ^* horizontal)



FIG. 4. Lindgrenite, b axis, first level (Mo) (c^* horizontal)

a and b axis levels are shown in Fig. 5, where the relative intensities of the diffraction spots on the photographs and extinctions not attributable to space group symmetry elements have been ignored. The center of each net is marked with a star and the intersection of the a axis with the b^*c^* nets of the first and second levels by a dot to the left of the center. The increasing off-set is due to the angle $(90-\beta^*)$ between a and a^* .

The directions of the b^* and c^* axes (b^*c^* nets, Fig. 5) are at 90° whereas the directions of the a^* and c^* axes (a^*c^* nets, Fig. 5) are not. This confirms the system as monoclinic.

By inspection of the b^*c^* nets it is at once apparent that the direct cell as selected is b -end centered. The doubled translation along b^* in the zero level photograph indicates a 2_1 screw axis. The change from the rectangle-like a^*c^* zero level net to the diamond-like nets of the a^*c^* upper levels reveals a glide plane of component $c/2$ (or the equivalent $a/2$ since the cell is b -end centered). The a^*c^* nets are characterised by a center of symmetry only and the b^*c^* nets by two symmetry lines at right angles. The diffraction symmetry, therefore, is $2/m$ and the diffraction symbol is $(2/m) B(2_1/c)$.

Results for the reciprocal lattice spacings and β^* angle are shown in Table 1. Two zero level b axis films obtained from different crystals were measured.

TABLE 1

Precession axis	d_a^*	d_b^*	d_c^*	β^*
b	0.1853	—	0.2144	$87^\circ 50'$
b	0.1853	—	0.2142	$87^\circ 43'$
a	—	0.1099	0.2144	—
average	0.1853	0.1099	0.2143	$87^\circ 46'$

Taking λ (CuK α) as 1.5418 Å (4), the direct cell constants are

$$a = 1.5418/0.1853 = 8.321 \text{ Å}$$

$$b = 1.5418/0.1099 = 14.03 \text{ Å}$$

$$c = 1.5418/0.2143 = 7.195 \text{ Å}$$

$$\beta = (180 - \beta^*) = 92^\circ 14',$$

$$\text{Volume (V) of the unit cell} = abc \sin \beta \\ = 839.19 \text{ Å}^3$$

With a specific gravity of 4.26, a formula weight (M) of 544.63 (3Cu, 190.71; 2Mo, 191.90; 10 O, 160.00; 2H, 2.016) chemical atomic mass units and using the density formula (4), $\rho = 1.6602 \text{ ZM/V}$, the number of formula units per cell,

$$Z = \frac{4.26 \times 839.19}{1.6602 \times 544.63} = 3.95 \approx 4.$$

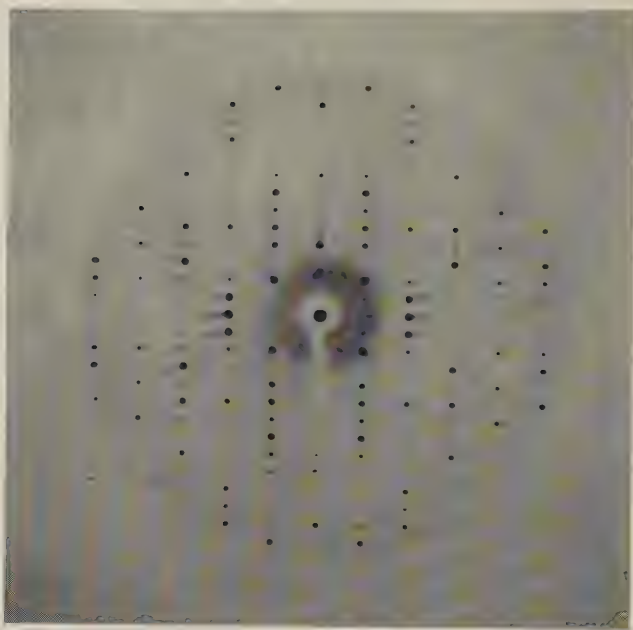


FIG. 7. Lindgrenite, new a axis, zero level (Mo) (new c^* horizontal)

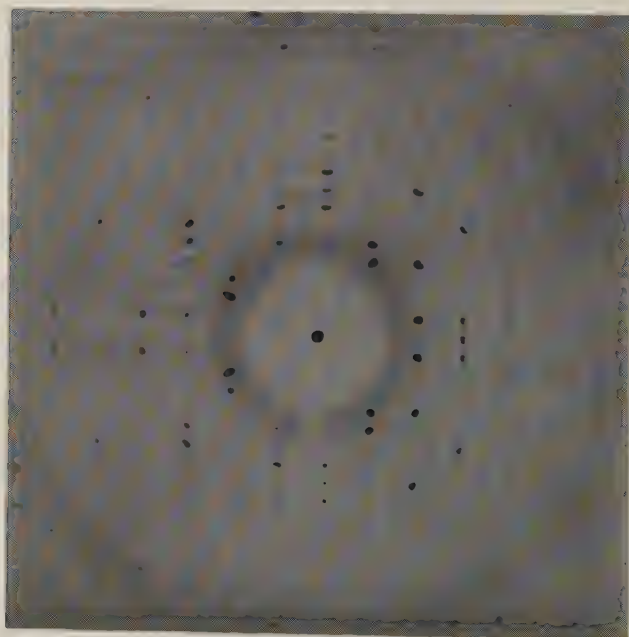


FIG. 8. Lindgrenite, new a axis, first level (Mo) (new c^* horizontal)

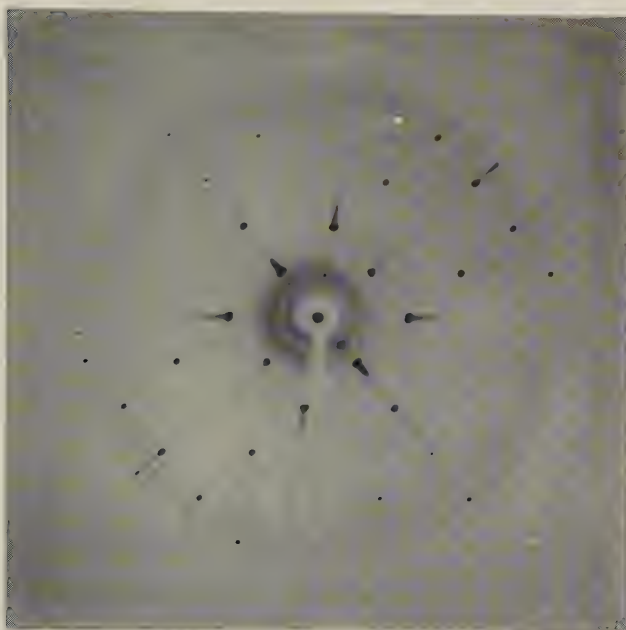


FIG. 9. Lindgrenite, Δ axis, zero level (Mo) (new c^* horizontal)

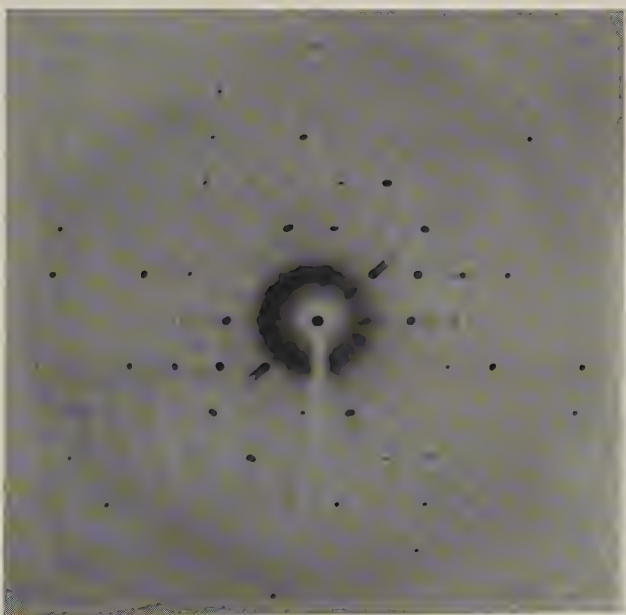


FIG. 10. Lindgrenite, b axis, first level (Mo) (new c^* horizontal)

However, since the foregoing cell is monoclinic and b -end centered, a primitive, and hence more desirable structural cell can be obtained by adopting the directions of the diagonals of the ac parallelogram as new a and c axes while retaining the original b axis, as shown in Fig. 6, where the base of the original cell (a, c, β) is represented by full lines and that of the new cell (a', c', β') by broken lines.

From the numerical data for the original cell it is, of course, a simple matter to compute corresponding data for the new (primitive) cell. As a

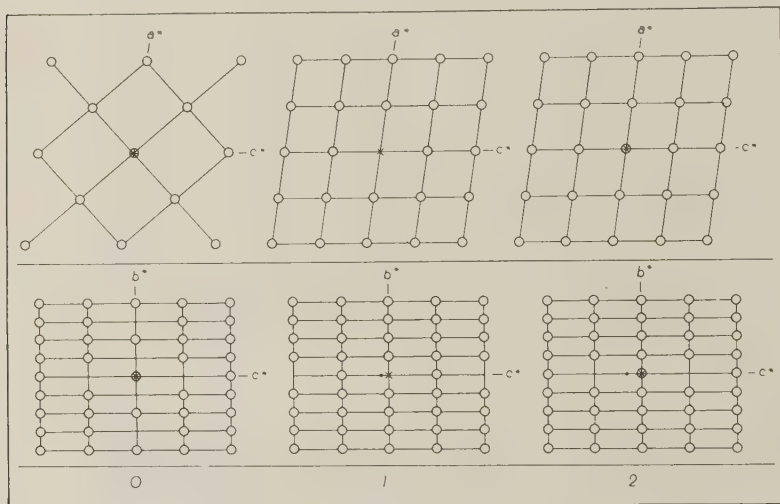


FIG. 11. 0, 1, 2 levels reciprocal lattice nets shown by (upper row) b^* and (lower row) c^* axis precession photographs of lindgrenite.
(New orientation, diffraction symbol $(2/M)P(2_1/n)$).

matter of interest in the precession camera, however, another lindgrenite crystal was mounted and precession photographs about the b axis (new orientation of a and c axes) and the new a axis were obtained for the zero, first and second reciprocal lattice levels in each case. Some of these are reproduced in Figs. 7, 8, 9, 10. A diagram of the plane nets is shown in Fig. 11. Simple inspection confirms the cell as primitive; the a^*c^* nets indicate an n glide plane (component, $a/2 + c/2$) perpendicular to b ; the doubled translation along b^* in the b^*c^* net of the a axis zero level again reveals the 2_1 screw axis along b . The diffraction symmetry of the new cell, therefore, is $2/m$, the diffraction symbol is $(2/m)P(2_1/n)$ and the space group is $P2_1/n$.

The constants of the new reciprocal lattice (obtained from direct

measurement of the zero level a and b axis films) are $d_a^* = 0.2747$, $d_b^* = 0.1096$, $d_c^* = 0.2853$, $\beta^* = 81^\circ 37'$.

The constants of the new cell derived by computation from the original unit and by direct measurement are listed in Table 2.

TABLE 2

	Old Cell	New Cell	
		Computed	Observed†
a	8.321 Å	5.604 Å	5.613 Å
b	14.03 Å	14.03 Å	14.07 Å
c	7.195 Å	5.393 Å	5.405 Å
β	$92^\circ 14'$	$98^\circ 19'$	$98^\circ 23'$
$a:b:c$	0.5931:1:0.5128	0.3994:1:0.3844	0.3989:1:0.3842

† The values for a , b , and c differ slightly from those reported at the 1947 meeting of The Crystallographic Society of America (5) because they have been recomputed from the measured values of d^* in terms of the currently accepted Ångström unit instead of the kX unit.

The agreement between the observed and computed values for the unit cell dimensions demonstrates that results obtained with the precession instrument are reproducible to 0.2% or 0.3% or better.

A precision measurement of the b translation to be described in another communication shows that 14.03 Å is the more probable value of b . This makes $a:b:c = 0.4001:1:0.3852$. The number of formula units per cell is $1.984 \approx 2$ and the calculated density is 4.295 g./cc.

The following transformation converts indices from the old to the new axes:

$$\begin{array}{rcl}
 \text{Old} & & \text{New} \\
 \frac{1-h}{2} & = & H \\
 k & = & K \\
 \frac{1+h}{2} & = & L
 \end{array}$$

ACKNOWLEDGMENTS

This work was carried out in Professor M. J. Buerger's laboratory of X-ray Crystallography at the Massachusetts Institute of Technology. I am greatly indebted to Professor Buerger and to other members of the Geology Department for their courtesy to me. I wish also to acknowledge the assistance of the John Simon Guggenheim Memorial Foundation in the form of a Fellowship and of McGill University, Montreal, for leave-of-absence.

REFERENCES

1. PALACHE, C., *Am. Mineral.*, **20**, 484-491 (1935).
2. BUERGER, M. J., The Photography of the Reciprocal Lattice, *A.S.X.R.E.D. Monograph No. 1* (1944).
3. BUERGER, M. J., *Am. Mineral.*, **30**, 553 (1945).
4. *J. Sci. Instrum.*, **24**, 27 (1947); *R.S.I.*, **18**, 688 (1947); *Am. Mineral.*, **32**, 591 (1947).
5. *Am. Mineral.*, **32**, 685 (1947).

SOME COMMENTS ON THE BUERGER PRECESSION METHOD FOR THE DETERMINATION OF UNIT CELL CONSTANTS AND SPACE GROUPS

WILLIAM H. BARNES,

National Research Council, Ottawa, Ontario, Canada.

ABSTRACT

Some comments on the effectiveness of the Buerger precession method and the method of de Jong and Bouman for unit cell and space group studies are made and certain practical advantages of the former are pointed out. A test of the accuracy of unit cell dimensions based on measurement of precession films is described. The effect of decreasing precession angles for upper levels in shortening exposure times is illustrated.

SOME COMMENTS ON THE BUERGER PRECESSION CAMERA

The Buerger precession method (1, 2), like the method of de Jong and Bouman (3), gives enlarged, undistorted pictures of the central areas of the reciprocal lattice of a crystal. The spacings of the rows of points and the interaxial angles of the plane level nets are obtained directly by measurements on the films themselves and are converted readily into axial translations and interaxial angles in direct space. Simple inspection of the plane nets of zero level photographs and comparison with those of upper levels is all that is required to establish the diffraction symbol of the crystal; no tedious indexing, plotting, or reconstruction of the reciprocal lattice is required. For purposes of detailed structure investigations, both methods, of course, suffer from the fact that the back-reflection range is not covered. For the establishment of space groups and the determination of unit cell constants to an ordinarily acceptable degree of accuracy, however, the Buerger precession camera and the de Jong-Bouman instrument are ideally suited; in certain respects, such as speed and absence of ambiguity, they are superior to other methods.

Although both de Jong-Bouman and Buerger precession films share the same desirable feature of undistorted reproduction of reciprocal lattice levels, the precession camera has certain advantages in practice. One of these is due to the relationship between the rotation axis of the goniometer head and the crystal axis normal to the reciprocal lattice level to be photographed. In the de Jong-Bouman instrument, as in simple rotating crystal and in Weissenberg cameras, the two coincide whereas they are at right angles to each other in the precession instrument. Thus in the de Jong-Bouman method the crystal must be reoriented (which usually involves remounting) on the goniometer head for a survey of the reciprocal lattice levels normal to a second crystallographic axis. Thus at least two mountings and orientations of a given crystal usually are required for a

complete unit cell and space group study. If the crystal lacks suitable faces for use on a two-circle reflecting goniometer, as in the case of a broken fragment, this may be very time-consuming and, in extreme cases, become a frustrating "trial and error" procedure. With the precession instrument, however, the precession axis is at right angles to that axis of the goniometer head which coincides with the rotation axis in other instruments and provision is made for locking the crystal in any angular position around this axis of the goniometer head. Levels normal to two precession axes, therefore, can be examined without remounting the crystal. This is particularly valuable in the case of crystals belonging to the cubic, tetragonal, orthorhombic, monoclinic, and hexagonal systems. Furthermore, as Professor Buerger has pointed out (2), if a small precession angle is employed, preferably without filter or layer-line screen, even the single orientation normally required can be effected solely by precession photographs.

Another useful consequence of the fact that the precession axis is at right angles to the axis of the goniometer head is that, with the usual precession angle of 20° , the axis of the goniometer head during precession makes a minimum angle of 70° with that of the pin-hole system. Thus there is ample clearance for the usual type of precision goniometer head with screw-adjustable arcs and lateral translations. On the other hand, this angle is reduced to 45° for the zero level in the most useful form of the de Jong-Bouman method (equal-cone with cone angle of 45°) which does not permit use of the usual size head with graduated arcs. Less bulky devices in which a ball-and-socket joint replaces the arcs and a sliding plane replaces the sledge motions (1, p. 184) can be employed, but only if accurate orientation of the crystal is possible by optical methods. The difficulty disappears for upper levels because the angle between the axis of the goniometer head (rotation axis) and that of the pin-hole system increases for constant cone angle and increasing height of level. Selection of a smaller cone angle to permit use of the larger head for the zero level, however, causes a rapid increase in the circular blank area in the center of the photographs of the first few upper levels (maximum when the height of the level equals the sine of the cone angle) and these are the ones that require shorter exposure times and hence are the most desirable to use.

Finally, it may be noted that exposure times for a specific reciprocal lattice level of a given crystal generally are longer with the de Jong-Bouman than they are with the precession camera.

THE ACCURACY OF THE PRECESSION METHOD

On several occasions doubts have been expressed regarding the accuracy with which unit cell dimensions can be obtained from measure-

ments of precession films as compared with other types such as Weissenberg photographs. Detailed data given in a recent communication (4) on the determination of the unit cell constants of probertite show that zero level photographs obtained with the rigid zero level cassette of the precession camera warrant use of the special measuring device developed by

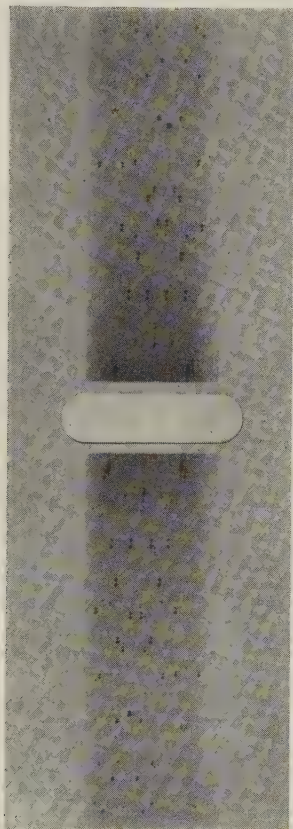


FIG. 1. Precision back-reflection Weissenberg photograph of lindgrenite. (Reflections from (010) lie on the central (symmetry) line).

Professor Buerger (5) that enables linear measurements to be made to 0.05 mm. and angular measurements to 5 minutes of arc. Results obtained during a recent investigation (6) of the unit cell dimensions of lindgrenite indicate a reproducibility of such constants to better than 0.2% or 0.3%, which compares favourably with other methods other than those designed specifically for very high precision.

As a test of the absolute accuracy of the precession method the length

of the b axis of lindgrenite was determined with Professor M. J. Buerger's precision back-reflection Weissenberg camera (1, chap. 21). A previous study (6) by the precession method had given 14.03 Å and 14.07 Å for this translation from two sets of films from separate crystals. Preliminary calculations for a large number of possible target materials showed that spots due to nine reflections ($n\lambda = 20\beta_1, 18\alpha_2, 18\alpha_1, 18\beta_1, 16\alpha_2, 16\alpha_1, 16\beta_1, 14\alpha_2, 14\alpha_1$) from (010) were potentially recordable within the limited range of the precision Weissenberg using unfiltered copper radiation. Two photographs of the same crystal were obtained using a modified Hadding gas tube and a Philips diffraction unit, respectively. They will be referred to as film 1 and film 2. The latter is reproduced in Fig. 1 and it will be observed that the shapes of the spots are not ideal for maximum precision of measurement. They are due to the tabular shape of the crystal fragment resulting from the fact that lindgrenite has perfect (010) cleavage. The films are sufficiently good, however, for the present purpose. The separation (F) of equivalent spots along a direction normal to the center line of the photographs was measured to 0.05 mm. Computations were made as described by Buerger (1, chap. 21) and based on the relations $d = (n\lambda/2)/\cos(F/4)$ and $\sin^2(90^\circ - \theta) = \sin^2(F/4)$. The following values (7) for λ were employed: $\text{CuK}\alpha_2$, 1.54434 Å; $\text{CuK}\alpha_1$, 1.54050 Å; $\text{CuK}\beta_1$, 1.39217 Å. Results are shown in Table 1.

TABLE 1

Cu $n\lambda$	Film 1			Film 2		
	F(mm.)	d(Å)	$\sin^2(90^\circ - \theta)$	F(mm.)	d(Å)	$\sin^2(90^\circ - \theta)$
$20\beta_1$	28.45	14.0298	0.015349	28.72	14.0317	0.015622
$18\alpha_2$		(absent)		31.52	14.0316	0.018796
$18\alpha_1$	35.30	14.0309	0.023581	35.32	14.0308	0.023563
$18\beta_1$		(absent)			(absent)	
$16\alpha_2$	113.00	14.0253	0.22403	113.07	14.0276	0.22429
$16\alpha_1$	114.10	14.0278	0.22817	114.07	14.0257	0.22793
$16\beta_1$	149.65	14.0227	0.36919	149.82	14.0299	0.36983
$14\alpha_2$	158.35	14.0267	0.40602	158.27	14.0235	0.40575
$14\alpha_1$	158.95	14.0223	0.40860	158.88	14.0196	0.40837

It will be observed that the spot due to $18\beta_1$ was not recorded on either film and that the one due to $18\alpha_2$ appeared only on film 2 which was given a longer exposure than film 1. The results tabulated for film 2 are the averages for three measurements made at different times. Corresponding values of F for the two films are in good agreement except for the spots due to $20\beta_1$ and $16\beta_1$. The difference (0.27 mm.) in the case of the $20\beta_1$

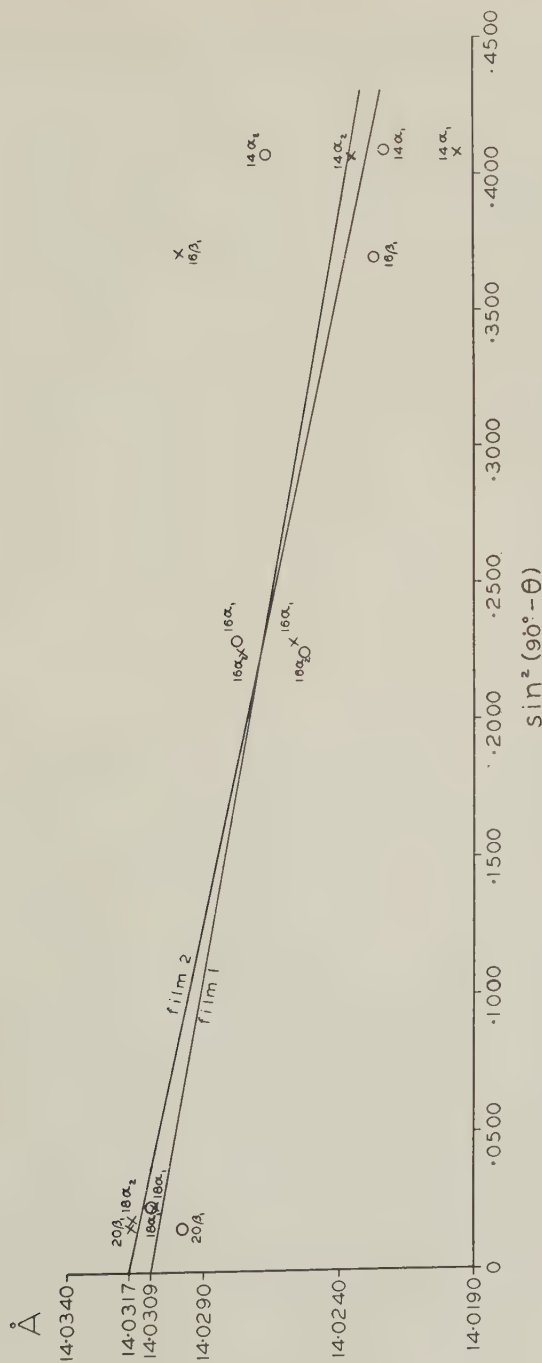


FIG. 2. Bradley-Jay plot of $d_{(010)}$ (b) against $\sin^2(90^\circ - \theta)$ for lindgrenite extrapolated to $\sin^2(90^\circ - \theta) = 0$.

spots is serious from the point of view of very high precision because points in this region, where $\sin^2 (90^\circ - \theta)$ approaches zero, have the greatest weight in determining the final value of d . For this reason, data for the two films have been plotted separately in Fig. 2, those for film 1 being represented by circles and those for film 2 by crosses. The scatter of points at higher values of $\sin^2 (90^\circ - \theta)$ is not as serious as it appears on the scale to which Fig. 2 has been drawn. For example, in the region of $\sin^2 (90^\circ - \theta) = 0.408$ an error of 0.10 mm. in F leads to a difference of about 0.005 \AA in the value of d and F is the difference between two measurements each of which is made only to the nearest 0.05 mm. In view of these factors, and particularly the discrepancy in the values for $20\beta_1$, the results for d at $\sin^2 (90^\circ - \theta) = 0$, namely, 14.0309 \AA and 14.0317 \AA , are in reasonable agreement. The average, $d = 14.031 \text{ \AA}$, probably is accurate to one or two units in the third decimal place. It certainly justifies the assumption that the absolute accuracy of results obtained by the precession method is as good as their reproducibility, namely, 0.2% to 0.3% or better.

THE EFFECT ON EXPOSURE TIME OF DECREASING THE PRECESSION ANGLE

Precession photographs of a given crystal require much shorter exposures than do Weissenberg photographs of the same level and they can be reduced still further by decreasing the precession angle. For the zero level it is desirable to record as much of the net as the $5'' \times 5''$ film will permit because measurements of row spacings and interaxial angles are best carried out on these pictures. The useful range of crystal-to-film distance (i.e., the magnification factor, F) is about 4.50 cm. to 7.50 cm. so that 6.00 cm. is a convenient setting; with this distance a precession angle of 20° is very satisfactory. Exposure times in general increase for upper levels and, if the precession angle remains constant, an unrecordably large area of the reciprocal lattice level may cut through the sphere of reflection during precession. The exposure time, therefore, can profitably be reduced by decreasing the angle of precession. Unfortunately in upper level photographs the effect of decreasing the precession angle is to increase the blank area in the center of the film as in the case of de Jong-Bouman photographs mentioned previously. However, for the purposes of a space group investigation this does not matter providing that the remaining annular record is broad enough to show the main features of the net. For example, Figs. 3 and 4 are precession photographs of the b -axis first level of childrenite obtained with Mo radiation (zirconium oxide filter). A precession angle of 20° was used for Fig. 3 and an exposure time of 3.5 hours whereas with a precession angle of $6^\circ 50'$ (corresponding to a cone angle of 20° between the precession axis and the diffracted rays) a some-

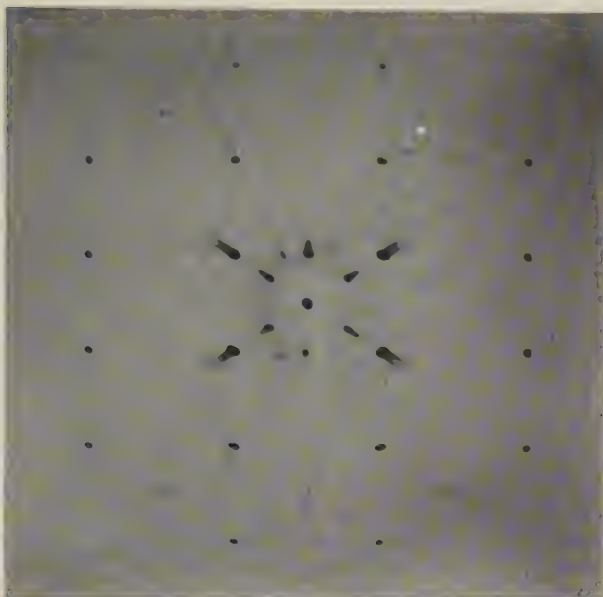


FIG. 3. *b* axis, first level, precession photograph of childrenite, Mo radiation, $\mu=20^\circ$, exposure 3.5 hrs.



FIG. 4. *b* axis, first level, precession photograph of childrenite, Mo radiation, $\mu=6^\circ 50'$, exposure 2.5 hrs.

what more dense photograph (Fig. 4) was obtained in 2.5 hours. As will be observed, the annular area of the plane net recorded in Fig. 4 is more than adequate for recognition of its main features, namely, diamond with the center of the net at a diamond corner (8).

ACKNOWLEDGMENTS

I am deeply indebted to Professor M. J. Buerger for his courtesy in placing his unique collection of moving-film equipment at my disposal. Grateful acknowledgment also is made to the John Simon Guggenheim Memorial Foundation for a Fellowship and to McGill University, Montreal, for leave-of-absence which made an extended visit to the Massachusetts Institute of Technology possible.

REFERENCES

1. BUEGER, M. J., *X-Ray Crystallography*, (Wiley), (1942).
2. BUEGER, M. J., *The Photography of the Reciprocal Lattice, A.S.X.R.E.D. Monograph No. 1*, (1944).
3. DE JONG, W. F. AND BOUMAN, J., *Zeit. Krist.*, (A) **98**, 456 (1938); *Physica*, **5**, 220 (1938).
4. BARNES, W. H., *Am. Mineral.*, **34**, 19-25 (1949).
5. BUEGER, M. J., *Am. Mineral.*, **30**, 553 (1945).
6. BARNES, W. H., *Am. Mineral.*, **34**, 163-172 (1949).
7. *J. Sci. Instrum.*, **24**, 27 (1947); *R.S.I.*, **18**, 688 (1947); *Am. Mineral.*, **32**, 591 (1947).
8. BARNES, W. H., *Am. Mineral.*, **34**, 16 (1949).

CRYSTALLOGRAPHY OF SPANGOLITE*

CLIFFORD FRONDEL,

Harvard University, Cambridge, Massachusetts.

ABSTRACT

Spangolite is shown by *x*-ray Weissenberg and morphological study to be ditrigonal-pyramidal (3 *m*) in crystallization. Unit cell dimensions: $a_0 = 8.245 \text{ \AA}$, $c_0 = 14.34$; $a_0:c_0 = 1:1.739$. Cell contents: $\text{Cu}_{12}\text{Al}_2(\text{SO}_4)_2(\text{OH})_{24}\text{Cl}_2 \cdot 6\text{H}_2\text{O}$. Transformation, morphological cell of Penfield (1890) to the structure cell, $\frac{1}{3}\frac{2}{3}00/\frac{1}{3}\frac{1}{3}00/i/000\frac{1}{2}$; $a:c = 1:1.741$ (Tombstone; Penfield, 1890). Space group $C3c$. Crystals of a hemimorphic habit from Bisbee, Arizona, and from a new locality at Majuba Hill, Pershing County, Nevada, are described. The indices of refraction of crystals from different localities vary measurably, with *O* ranging from 1.680 to 1.687; the variation probably is due to substitution of OH for Cl.

MORPHOLOGY

The rare and interesting mineral spangolite was first described in 1890 by Penfield, who established the formula as $\text{Cu}_6\text{Al}(\text{SO}_4)(\text{OH})_{12}\text{Cl} \cdot 3\text{H}_2\text{O}$ and on the basis of the evidence then available assigned the mineral to the hexagonal-scalenohedral (calcite) crystal class, $\bar{3} 2/m$. The locality was given only as within a radius of 200 miles of Tombstone, Arizona, and has not since been more clearly established. Penfield's material comprised

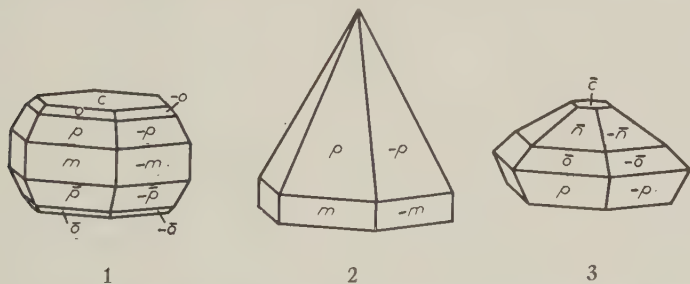


FIG. 1. Spangolite, Tombstone, Arizona. Pseudo-holohedral habit (after Penfield).

FIG. 2. Spangolite, Majuba Hill, Arizona. Antilogous pole up.

FIG. 3. Spangolite, Bisbee, Arizona. Antilogous pole down.

doubly terminated hexagonal tablets flattened on {0001} with large faces of a hexagonal prism and a series of inclined faces in a zone therewith. Etch figures produced by very dilute acids on {0001} exhibited rhombohedral symmetry, and the inclined faces, which seemingly conformed to six-fold symmetry about [0001], were set as pyramids together with the prism in the second order position. The crystals were specifically stated

* Contribution from the Department of Mineralogy and Petrography, Harvard University, No. 302.

to show no evidence of lower than hexagonal holohedral symmetry (Fig. 1). The spangolite crystals described by Pelloux from Arenas, Sardinia, also are hexagonal holohedral in appearance. Miers, however, described an occurrence of the mineral in Cornwall and proved by means of pyroelectric and etching tests that the $[0001]$ axis was polar. Some of his crystals had a hemimorphic appearance, but the curved and tapering nature of the faces precluded goniometric measurements. Ford later mentioned but did not describe crystals of a hemimorphic habit from the Grand Central mine, Tintic, Utah.

A few months ago, Mr. Hatfield Goudey of Yerington, Nevada, found a new occurrence of spangolite at Majuba Hill, Pershing County, Nevada, and kindly offered specimens for study. The mineral forms thin crusts of minute crystals associated with azurite, chalcophyllite and cyanotrichite on altered rhyolite. The spangolite crystals are sharply developed and have a simple and strikingly hemimorphic habit. Examination under a high power binocular microscope showed that the crystals were terminated at one end—often the point of attachment to the matrix—by a basal pinacoid, with a hexagonal prism and a seeming hexagonal pyramid which tapered out to a sharp point or was terminated by a small basal pinacoid. A few crystals about 0.003 inch in size were mounted on a reflecting goniometer by picking them up under a microscope on the point of a needle that had been thinly coated with a tacky wax. Visible although inferior reflections were obtained which served to identify the forms listed in Table 2; the forms are here given in the new orientation required by the x -ray study described beyond. The habit is shown in Fig. 2, the acute termination being arbitrarily taken as the antilogous pole. Crystals of a different habit were found on another specimen from this locality. These comprised minute hexagonal prisms attached to the matrix by one end of the c -axis and terminated at the other end of this axis by a slightly concave basal pedion. A few of these crystals were noted to have a rounded three-sided cross section, resembling that of tourmaline, but the roughness of the prism faces prevented goniometric measurement.

Material better suited for goniometric study was obtained on a specimen of spangolite from the Czar mine, Bisbee, Arizona, purchased for the Harvard collection in 1941. These crystals were thin tabular on $\{0001\}$ and are doubly terminated with a hemimorphic habit as shown in Fig. 3. The trigonal pyramids $\{10\bar{1}1\}$ and $\{01\bar{1}1\}$ [new orientation] were consistently observed on only one pole of $[0001]$, here taken as the antilogous pole. The other forms occasionally occurred at both poles but usually were present only at the analogous pole. $\{0001\}$ and $\{000\bar{1}\}$ always were different in size, with $\{000\bar{1}\}$ largest. Adjacent inclined faces on both the top and bottom poles of the crystals are commonly equal in size, and

when they are not equal the distortion is of a random rather than of a three-fold nature. The inclined faces and the prism faces ordinarily are deeply striated and grooved horizontally, but no correlation between these markings could be distinguished on either alternate or adjacent faces. The inclined faces on the antilogous termination of the crystals ordinarily are more deeply striated. These remarks apply also to the crystals from Majuba Hill and to the crystals from Tintic mentioned beyond. Morphologically, there is no evidence of trigonal symmetry in the arrangement of the inclined faces on spangolite although *x*-ray study proves that the seeming pyramids actually are sets of positive and negative trigonal pyramids. The $\{10\bar{1}3\}$ and $\{01\bar{1}3\}$ faces of the crystals are relatively smooth and large and afforded a number of measures of fair quality. The average of these gave $\rho = 33^\circ 44'$, which is in satisfactory agreement with the value $33^\circ 50'$ calculated from the morphological ratio of Penfield. His ratio was based on the angle $\rho = 63^\circ 33\frac{1}{2}'$ obtained from faces of $\{10\bar{1}1\}$ and $\{01\bar{1}1\}$ of superior quality on an otherwise deeply striated crystal. The specific gravity of the Bisbee material was determined on the microbalance as 3.135 ± 0.01 .

Crystals from the Tintic locality mentioned by Ford also were available for study. These were dull in luster and strongly striated but measurements of sufficient accuracy to identify the forms present (Table 2) were obtained. The crystals have a decided hemimorphic appearance, but this is due to an oscillatory combination of $\{10\bar{1}1\}$ and $\{01\bar{1}1\}$ with $\{10\bar{1}0\}$ at the antilogous pole of the crystals only, causing the crystals to taper at this pole in an irregular fashion, and is not due to asymmetry in the kind of faces developed at the top and bottom poles. The crystals from Cornwall described by Miers probably also were of this nature.

X-RAY CRYSTALLOGRAPHY

Tiny doubly terminated crystals from the Tintic and the Bisbee localities were examined by the rotation and the Weissenberg methods. Relatively long exposures were taken in copper radiation and photographs of excellent quality resulted. The rotation period about the perpendicular to the morphological $\{11\bar{2}0\}$ in Penfield's orientation proved to be $\sqrt{3}$ times larger than that about the horizontal axis at 30° thereto. This finding identifies the principal prism as of the first order, and the supposed pyramids become sets of trigonal pyramids in equal development. 0- and *n*-layer Weissenberg photographs about the *c*-axis showed the plane symmetries C_{6l} and C_{3l} and proved the lattice type to be hexagonal. 0- and *n*-layer photographs about the morphological *a*-axis (in the new orientation) showed only two-fold axes of symmetry, C_2 . The 0-layer about the axis perpendicular thereto revealed a two-fold axis and plane of symmetry, C_{2l} , and the 1-layer showed a plane of symmetry only, C_l .

These layer symmetries identify the centrosymmetrical point group of the crystal as $\bar{3}m$, which includes the crystal classes $3m$, 32 and $\bar{3}2/m$. The polar nature of $[0001]$ as proven by morphological and physical evidence establishes the crystal class as ditrigonal-pyramidal, $3m$ (tourmaline class). The space group is $C_{3v}^2 = C3c$. Spangolite was earlier placed in the tourmaline crystal class by Ford in the 4th edition of Dana's *Textbook of Mineralogy* but without discussion of the basis for this classification. The unit cell dimensions (new wavelengths) and ratio obtained by calculation from the appropriate 0-layer Weissenberg films are:

$$a_0 = 8.245 \pm 0.01 \text{ \AA}, c_0 = 14.34 \pm 0.01, a_0:c_0 = 1:1.739,$$

An angle table in the new orientation using the elements obtained by Penfield on the Tombstone material is given in Table 1. Penfield's elements are very close to the x -ray values. A list of the forms observed on crystals from the known localities is given in Table 2. The transformation from the original morphological orientation to the structure cell is $\frac{1}{3}\frac{2}{3}00/\frac{1}{3}\frac{1}{3}00/i/000\frac{1}{2}$. The x -ray powder spacing data obtained in filtered copper radiation on Tintic crystals are given in Table 3.

TABLE 1. ANGLE TABLE FOR SPANGOLITE

$$a:c = 1:1.7414; \alpha 75^\circ 17'; p_0:r_0 = 2.0108:1; \lambda 101^\circ 41\frac{1}{2}'$$

Lower	Upper	Miller	ϕ	$\rho = C$	A_1	A_2
\bar{c}	c 0001	111	—	0°00'	90°00'	90°00'
	m 10 $\bar{1}0$	2 $\bar{1}1$	30°00'	90 00	30 00	90 00
	—m 01 $\bar{1}0$	11 $\bar{2}$	—30 00	90 00	90 00	30 00
	a 11 $\bar{2}0$	10 $\bar{1}$	0 00	90 00	60 00	60 00
\bar{k}	k 10 $\bar{1}4$	211	30 00	26 41 $\frac{1}{2}$	67 06 $\frac{1}{2}$	90 00
\bar{n}	n 10 $\bar{1}3$	522	30 00	33 50	61 10 $\frac{1}{2}$	90 00
\bar{o}	o 10 $\bar{1}2$	411	30 00	45 09 $\frac{1}{2}$	52 01	90 00
\bar{r}	r 30 $\bar{3}4$	10.1.1.	30 00	56 27	43 48	90 00
\bar{l}	l 60 $\bar{6}7$	19.1.1	30 00	59 52 $\frac{1}{2}$	41 29 $\frac{1}{2}$	90 00
\bar{p}	p 10 $\bar{1}1$	100	30 00	63 33 $\frac{1}{2}$	39 09 $\frac{1}{2}$	90 00
\bar{x}	x 30 $\bar{3}2$	8 $\bar{1}1$	30 00	71 39 $\frac{1}{2}$	34 42 $\frac{1}{2}$	90 00
\bar{y}	y 20 $\bar{2}1$	5 $\bar{1}1$	30 00	76 02	32 49	90 00
\bar{z}	z 30 $\bar{3}1$	722	30 00	80 35 $\frac{1}{2}$	31°18 $\frac{1}{2}$	90 00
— \bar{k}	—k 01 $\bar{1}4$	552	—30 00	26 41 $\frac{1}{2}$	90 00	67 06 $\frac{1}{2}$
— \bar{n}	—n 01 $\bar{1}3$	441	—30 00	33 50	90 00	61 10 $\frac{1}{2}$
— \bar{o}	—o 01 $\bar{1}2$	110	—30 00	45 09 $\frac{1}{2}$	90 00	52 01
— \bar{r}	—r 03 $\bar{3}4$	772	—30 00	56 27	90 00	43 48
— \bar{l}	—l 06 $\bar{6}7$	13.13. $\bar{5}$	—30 00	59 52 $\frac{1}{2}$	90 00	41 29 $\frac{1}{2}$
— \bar{p}	—p 01 $\bar{1}1$	22 $\bar{1}$	—30 00	63 33 $\frac{1}{2}$	90 00	39 09 $\frac{1}{2}$
— \bar{x}	—x 03 $\bar{3}2$	55 $\bar{4}$	—30 00	71 39 $\frac{1}{2}$	90 00	34 42 $\frac{1}{2}$
— \bar{y}	—y 02 $\bar{2}1$	11 $\bar{1}$	—30 00	76 02	90 00	32 49
— \bar{z}	—z 03 $\bar{3}1$	44 $\bar{5}$	—30 00	80 35 $\frac{1}{2}$	90 00	31 18 $\frac{1}{2}$

TABLE 2. FORMS OBSERVED ON SPANGOLITE FROM
DIFFERENT LOCALITIES

Forms	Tomb- stone†	Majuba Hill	Bisbee	Tintic	Sardinia	Cornwall
0001	*	* rare	*	* rare	*	*
000 $\bar{1}$	*	*	*	*	*	
10 $\bar{1}$ 0	*	*		*	*	*
01 $\bar{1}$ 0	*	*		*	*	*
11 $\bar{2}$ 0	*			* rare	*	*
10 $\bar{1}$ 3	*		* rare			
01 $\bar{1}$ 3	*		* rare			
01 $\bar{1}$ 3	*		*			
10 $\bar{1}$ 3	*		*			
10 $\bar{1}$ 2	*					
01 $\bar{1}$ 2	*					
10 $\bar{1}$ 2	*		*			
01 $\bar{1}$ 2	*		*			
10 $\bar{1}$ 1	*	*	*	*	*	*
01 $\bar{1}$ 1	*	*	*	*	*	*
10 $\bar{1}$ 1	*			*	*	?
01 $\bar{1}$ 1	*			*	*	?

† Also the following trigonal pyramids with their corresponding negative upper and positive and negative lower geometrical equivalents: 10 $\bar{1}$ 4, 30 $\bar{3}$ 4, 30 $\bar{3}$ 2, 20 $\bar{2}$ 1, 30 $\bar{3}$ 1.

TABLE 3. X-RAY POWDER DIFFRACTION DATA FOR
SPANGOLITE FROM TINTIC, UTAH
Copper radiation, nickel filter

d	I	d	I	d	I
7.07	10	1.75	1	1.27	2
3.59	8	1.64	3	1.25	1
3.20	2	1.56	4	1.23	1
2.77	1	1.53	1	1.20	1
2.66	4	1.49	4	1.18	3
2.54	7	1.43	2	1.13	1
2.36	5	1.39	2	1.09	2
2.17	4	1.35	1	1.08	1
2.07	1	1.33	1	1.02	1
1.98	6	1.31	2	1.01	1
1.80	7	1.29	1	1.005	2
				0.987	2

CHEMISTRY AND INDICES OF REFRACTION

The only chemical analyses reported of spangolite are those of Penfield on the original material from the region of Tombstone, Arizona. Table 4 gives the unit cell contents calculated from the average of these

analyses using the cell dimensions cited and the specific gravity, 3.141, obtained by Penfield on the analyzed sample and here confirmed on material from Bisbee. The simplest formula for the mineral is seen to be



which is identical with that originally derived by Penfield. There are two of these formula units in the unit cell.

TABLE 4. UNIT CELL CONTENTS OF SPANGOLITE

	1	2	3	4	5	6
CuO	59.82	59.51	.7479	(Cu) .7479	11.94	12
Al ₂ O ₃	6.39	6.60	.0647	(Al) .1295	2.07	2
SO ₃	10.03	10.11	.1263	(S) .1263	2.01	2
Cl	4.44	4.11	.1159	(Cl) .1159	1.85	2
H ₂ O	20.32	20.41	1.133	(H) 2.2652	36.17	36
				(O) 2.3960	38.26	38
	101.00	100.74				
O = Cl	1.00	0.92				
Total	100.00	99.82				

1. Average of four analyses, three partial, by Penfield (1890) on material from the region of Tombstone, Arizona. Measured $G=3.141$.

2. Theoretical weight percentages for $\text{Cu}_6\text{Al}(\text{SO}_4)(\text{OH})_{12}\text{Cl} \cdot 3\text{H}_2\text{O}$.

3. Molecular quotients.

4. Atomic quotients.

5. Calculated unit cell contents. Molecular weight = 1597 (meas.).

6. Theoretical cells contents. Calculated $G=3.14$.

The calculated atomic contents of the unit cell correspond very closely to whole numbers with the exception of Cl. The value for Cl is slightly low and presumably this element is substituted for in part by OH. A small but significant variation is found in the indices of refraction and

Locality	<i>O</i>	<i>E</i>
New Mexico ^b	1.680	
Majuba Hill, Arizona	1.681 ± .002	1.627 ± 0.002
Sardinia ^b	1.682	
Sardinia	1.683 ± .002	
Bisbee, Arizona	1.685 ± .002	
Tintic, Utah	1.686 ± .002	1.638 ± 0.002
Tombstone, Arizona ^a	1.687	
Tombstone, Arizona ^c	1.694	1.641

^a Private communication, Miss Jewell Glass, U. S. Geol. Survey.

^b Private communication, Dr. Waldemar T. Schaller, U. S. Geol. Survey.

^c Penfield (1890).

birefringence of spangolite from different localities, as tabulated below. This variation doubtless is due to variation in the Cl:OH ratio or to some other type of compositional variation in the mineral. It may be noted that at least the index of refraction for the ordinary ray given by Penfield for the Tombstone material is in error according to the measurements of Miss Glass on the type material.

SYSTEMATIC RELATIONS

Spangolite does not appear to have any close relatives either crystallographically or chemically. A number of other hydrated basic sulfates of divalent and trivalent cations are known and are listed below. A comparison of the properties of these minerals with those of spangolite, including a comparison of the x-ray powder photographs, did not reveal

Connellite	$\text{Cu}_{18}(\text{SO}_4)(\text{OH})_{30}\text{Cl}_4 \cdot 4\text{H}_2\text{O}$ (?)
Glaucocerinite	$\text{Zn}_{13}\text{Cu}_7\text{Al}_8(\text{SO}_4)_2(\text{OH})_{60} \cdot 4\text{H}_2\text{O}$ (?)
Creedite	$\text{Ca}_3\text{Al}_2(\text{SO}_4)(\text{OH}, \text{F})_6\text{F}_4 \cdot 2\text{H}_2\text{O}$
Spangolite	$\text{Cu}_6\text{Al}(\text{SO}_4)(\text{OH})_{12}\text{Cl} \cdot 3\text{H}_2\text{O}$
Chalcophyllite	$\text{Cu}_{28}\text{Al}_2(\text{SO}_4)_3(\text{OH})_{33}(\text{AsO}_4)_3 \cdot 33\text{H}_2\text{O}$
Cyanotrichite	$\text{Cu}_4\text{Al}_2(\text{SO}_4)(\text{OH})_2 \cdot 2\text{H}_2\text{O}$
Zinkaluminite	$\text{Zn}_3\text{Al}_3(\text{SO}_4)(\text{OH})_{13} \cdot 3\text{H}_2\text{O}$
Chalcoalumite	$\text{CuAl}_4(\text{SO}_4)(\text{OH})_{12} \cdot 3\text{H}_2\text{O}$
Ettringite	$\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12} \cdot 26\text{H}_2\text{O}$

any obvious relationships. The powder pattern of chalcophyllite, however, resembles that of spangolite in part, due to a near identity in position of intense reflections from 000*l*. The cell dimensions and cell contents of spangolite and chalcophyllite* are compared below.

	Cell contents	Space group	a_0	c_0
Spangolite	$\text{Cu}_{12}\text{Al}_2(\text{SO}_4)_2(\text{OH})_{24}\text{Cl}_2 \cdot 6\text{H}_2\text{O}$	$C3c$	8.245 (14.34 × 4 = 57.36)	14.34
Chalcophyllite	$\text{Cu}_{18}\text{Al}_2(\text{SO}_4)_3(\text{OH})_{33}(\text{AsO}_4)_3 \cdot 33\text{H}_2\text{O}$	$R \bar{3} m$ (?)	10.75	57.40

* Data of L. G. Berry, private communication, 1948.

ACKNOWLEDGMENT

The writer wishes to express his thanks to Miss Mary Mrose for her assistance in the preparation of the manuscript and in the computations.

REFERENCES

- FORD, W. E., *Am. Jour. Sci.*, **38**, 502 (1914).
 MIERS, H. A., *Mineral. Mag.*, **10**, 273 (1894).
 PELLOUX, A., *Ann. Mus. Civico Genova*, **4**, ser. 3a, 194 (1909).
 PENFIELD, S. L., *Am. Jour. Sci.*, **39**, 370 (1890).

RETGERSITE, $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$, A NEW MINERAL*

CLIFFORD FRONDEL AND CHARLES PALACHE,
Harvard University, Cambridge, Mass.

ABSTRACT

The well-known artificial compound, tetragonal $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$, is described from five natural occurrences: with morenosite and minasragrite at Minasragra, Peru; with annabergite at Cottonwood Canyon, Churchill Co., Nevada; at Lobenstein, Thuringia; at Lichtenberg, Bayreuth, Bavaria; and with ferroan chalcantite at the Gap Nickel Mine, Lancaster Co., Pennsylvania. Tetragonal trapezohedral, with $a:c=1:2.7038$ (artificial; Scacchi, 1863); $a_0=6.765$ kX, $c_0=18.20$; $a_0:c_0=1:2.690$ (Minasragra). Uniaxial negative, with $O=1.510$, $E=1.486$ (natural). Crystals from Minasragra are short prismatic $\{001\}$ with $\{001\}$, $\{110\}$, $\{011\}$, $\{012\}$, $\{112\}$; also found as fibrous aggregates and veinlets. Color blue-green. $G=2.04$ (Nevada). Cleavage $\{001\}$ perfect, $\{110\}$ in traces. Analysis gave: NiO 26.87, MgO 0.65, FeO 0.63, SO_3 30.32, H_2O [41.53], total [100.00] (Nevada). The name retgersite is proposed for the mineral in honor of J. W. Retgers (1856–1896), Dutch physical chemist and crystallographer.

Only four of the twenty-three reported natural occurrences of morenosite, orthorhombic $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$, can be said definitely to be of that species.

INTRODUCTION

At least six different hydrates of nickel sulfate and an uncertain number of nickel oxysulfates have been synthesized (9, 12, 13). Several of these compounds have regions of stability which suggest that they might form under natural conditions, and one of them, the orthorhombic polymorph of $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$, is already known to mineralogists under the name morenosite. Most of the reported occurrences of morenosite are open to doubt as to the particular nickel sulfate represented, due to uncertainties as to the system of crystallization and the water content. A recent survey of the specimens of so-called morenosite in the Harvard collection verified the existence of morenosite in one instance and also proved the natural existence of the tetragonal polymorph of nickel sulfate hexahydrate. The latter substance, also known as blue- or alpha- $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$, is described beyond under the name retgersite. The name is given after the Dutch physical chemist and chemical crystallographer Jan Willem Retgers (1856–1896). Retgers made numerous crystallographic studies of artificial salts with particular reference to their isomorphism and polymorphism. Retgers also made important contributions to mineralogical laboratory techniques, including the use of phosphorus as an index of refraction medium, the examination of detrital mineral grains by embedding techniques, and especially the development

* Contribution from the Department of Mineralogy and Petrography, Harvard University, No. 301.

and use of heavy liquids and melts for the measurement of specific gravity.

RETGERSITE, $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$

The tetragonal polymorph of $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ was first identified by the senior author as poorly formed, bluish green crystals incrusting a black coke-like mass of patronite from Minasragra, Peru. The crystals, which ranged up to about one millimeter in length, were too rough to permit accurate goniometric measurements but did afford sufficient data to establish the forms present as $\{001\}$, $\{110\}$, $\{011\}$, $\{012\}$ and $\{112\}$. The habit is shown in Fig. 1. An x-ray rotation photograph and 0-layer Weis-

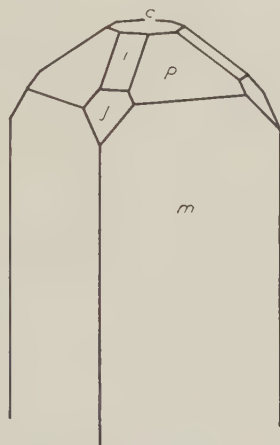


FIG. 1. Retgersite from Minasragra, Peru. Forms: $c\{001\}$, $m\{110\}$, $p\{112\}$, $j\{011\}$, $i\{012\}$.

senberg photograph taken about $[001]$ confirmed the tetragonal symmetry and afforded the cell dimensions given below in comparison with those obtained by a precision powder x-ray study of the artificial compound by Borghijs (2).

a_0
 $6.765 \pm 0.02 \text{ kX}$
 6.776 ± 0.003

c_0
 $18.20 \pm 0.05 \text{ (Minasragra)}$
 $18.249 \pm 0.009 \text{ (Artificial (2))}$

Accurate morphological measurements were obtained by Scacchi (15) on artificial crystals, and an angle table for the known forms using his angles as given in Table 1. The original morphological cell of Scacchi is here turned 45° around $[001]$ to conform to the unit of the structure cell. The crystal structure of the compound has been described by Beevers and Lipson (1). Optically, the Minasragra mineral is uniaxial negative with $n_O = 1.510$ and $n_E = 1.486$, which compare closely with the indices

TABLE 1. ANGLE TABLE FOR RETGERSITE
Tetragonal; trapezohedral—4 2 2
 $a:c=1:2.7038$; $p_0:r_0=2.7038:1$

	ϕ	ρ	A	M
<i>c</i> 001	—	0°00'	90°00'	90°00'
<i>m</i> 110	45°00'	90 00	45 00	90 00
<i>h</i> 013	0 00	42 01½	90 00	61 44½
<i>i</i> 012	0 00	53 30½	90 00	55 21½
<i>j</i> 011	0 00	69 42	90 00	48 27½
<i>o</i> 113	45 00	51 53	56 12	90 00
<i>p</i> 112	45 00	62 23½	51 12	90 00

$n_O=1.5109$ and $n_E=1.4873$ (for Na) obtained by the prism method of Topsøe and Christiansen (19) on artificial crystals. There is a good cleavage on {001} and traces of a cleavage, best seen on crushed grains under the microscope, on {110}. Sufficient material could not be obtained for a chemical analysis. The mineral occurs with morenosite, described beyond in more detail, and with blue efflorescent masses of minasragrite, $V_2H_2(SO_4)_3O_2 \cdot 15H_2O$. The latter substance unquestionably has formed at least in part since the specimen was collected but both the retgersite and morenosite appear to be original deposits. Both minerals presumably were formed ultimately by the oxidation of nickelian pyrite present in the ore-body.

Four additional natural occurrences of retgersite were found on specimens from other localities that had been labeled as of morenosite. The best of these comprised a foot-long mass of niccolite-bearing vein material from a mine in Cottonwood Canyon, Churchill County, Nevada, which was supplied for study through the interest of Mr. Hatfield Goudey of Yerington, Nevada. The geology of the deposit has been described by Ferguson (6). The specimen has been thoroughly oxidized and is crusted over and veined by apple-green, granular masses of annabergite and blue-green fibrous aggregates of retgersite. The retgersite is an original deposit, in part earlier formed than annabergite, and is not a dehydration product of morenosite. Optically, the retgersite is uniaxial negative with $n_O=1.510$ and $n_E=1.486$. The x-ray powder pattern checked that of artificial tetragonal $NiSO_4 \cdot 6H_2O$. The direction of the fiber axis is [001]. The specific gravity of a small compact grain was determined on the microbalance as 2.04, which compares to the values 2.064 and 2.074 obtained by Gossner (7) and Topsøe (18), respectively, on artificial crystals. A chemical analysis of this material is cited in Table 2. The Mg and part at least of the Fe^{2+} is present in substitution for Ni.

Retgersite also was identified as pale blue-green granular crusts and

TABLE 2. ANALYSIS OF RETGERSITE FROM COTTONWOOD CANYON, NEVADA

	1	2
NiO	26.87	28.42
MgO	0.65	
FeO	0.63	
SO ₃	30.32	30.46
H ₂ O	[41.53]	41.12
Total	[100.00]	100.00

1. Analysis by H. J. Hallowell, May, 1948. Analysis made on a cold water extract of material slightly admixed with limonite, quartz, and annabergite. The total iron is calculated as FeO, but is probably present in the mineral in part as admixed Fe₂O₃.

2. Theoretical composition, NiSO₄ · 6H₂O.

veinlets associated with fine-grained annabergite on a specimen labeled morenosite from Lichtenstein, Bayreuth, Bavaria. This is the type locality for the supposed variety of morenosite termed pyromeline by von Kobell (22). One cannot tell from the original description, however, whether his mineral was either retgersite or morenosite. Pyromeline was said on the basis of qualitative tests to contain a small amount of (AsO₄) in substitution for (SO₄) but this might well have been due to admixture of annabergite. Sufficient material was not available on the present specimen to permit an analysis. The indices of refraction of this material are practically identical with those of the pure artificial compound. Additional occurrences of retgersite were found as pale blue-green masses associated with annabergite on a specimen from Lobenstein, Thuringia, and with ferroan chalcantinite on a specimen from the Gap Nickel Mine, Lancaster Co., Pennsylvania.

Systematic Relations and Synthesis. Retgersite is isostructural with the tetragonal polymorphs of the hexahydrated selenates of Ni and Zn. Some of the properties of these compounds are given in Table 3. Retgersite is the only known natural representative of the group. The monoclinic polymorph of NiSO₄ · 6H₂O has been prepared artificially and its crystallographic and optical properties have been described (8, 9). This compound, green in color, is formed from pure water solutions at temperatures over 53.3° C. and below this temperature rapidly inverts to the blue tetragonal polymorph. The occurrence of this unstable and relatively soluble (52.5 g. NiSO₄ in 100 g. water at 54.5°) monoclinic phase in nature seems very unlikely. The monoclinic zinc and magnesium analogues are stable under ordinary conditions, however, and occur in nature as the minerals bianchite and hexahydrite.

Mg can substitute for Ni in retgersite, as indicated by the analysis of

the Nevada material, and at least a partial series extends from retgersite toward tetragonal $\text{MgSO}_4 \cdot 6\text{H}_2\text{O}$. There is no experimental proof of this at hand, however, and pure tetragonal $\text{MgSO}_4 \cdot 6\text{H}_2\text{O}$ itself is not stable under ordinary conditions. It may be noted in this connection that a complete series extends between the orthorhombic compounds morenosite, $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$, and epsomite, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, as shown by Dufet (5) and by Hutton (10). Both Fe'' and Cu'' probably substitute only to a very small extent in retgersite. The observed limits of substitution of these elements in orthorhombic $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$ are $\text{Cu}:\text{Ni} \sim 2:98$ and $\text{Fe}:\text{Ni} \sim 1:5$. Neither Fe'' or Cu'' form stable compounds in either the tetragonal or

TABLE 3. TETRAGONAL HEXAHYDRATED SULFATES AND SELENATES*

		$a:c$ (morph.)	a_0	c_0	$n\text{O}$ (for Na)	$n\text{E}$
Retgersite	$\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$	1:2.7038	6.776	18.249	1.5109	1.4873
(Artificial)	$\text{NiSeO}_4 \cdot 6\text{H}_2\text{O}$	1:2.5971			1.5393	1.5125
(Artificial)	$\text{ZnSeO}_4 \cdot 6\text{H}_2\text{O}$	1:2.6798			1.5291	1.5039
(Unstable)	$\text{CuSO}_4 \cdot 6\text{H}_2\text{O}$					
(Unstable)	$\text{ZnSO}_4 \cdot 6\text{H}_2\text{O}$					
(Unstable)	$\text{MgSO}_4 \cdot 6\text{H}_2\text{O}$					

* Data summarized from Groth (8); cell dimensions of Borghijs (2).

monoclinic hexahydrate groups or in the orthorhombic heptahydrate group, although a metastable tetragonal modification of $\text{CuSO}_4 \cdot 6\text{H}_2\text{O}$ has been reported and the orthorhombic form of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ has been said on the basis of inconclusive evidence to exist in nature (the tauriscite of Volger (21)). Mn'' probably enters into a limited range of substitution for Ni in retgersite.

Retgersite can be synthesized by crystallization from pure water solution at temperatures between 31.5° , below which orthorhombic $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$ is stable, and 53.3° , above which monoclinic $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ is stable. A dihydrate forms above about 118° . These transition temperatures are from the data of Steele and Johnson (17); slightly different values have been reported by others (see Seidell (17)), and metastable equilibria commonly occur. Retgersite also can crystallize at temperatures at least as low as 0° from solutions which contain an appropriate excess of free H_2SO_4 , as shown by Rohmer (14) and others. This factor may determine its formation in nature in place of morenosite. Under certain circumstances both retgersite and morenosite have been observed to crystallize simultaneously, one or the other of the two compounds being in metastable equilibrium.

MORENOSITE, $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$

At least twenty-three different occurrences of morenosite have been reported in the literature by Laspeyres (11) and others. In only a few instances, however, have sufficient data been given to definitely prove the occurrence of the orthorhombic heptahydrate. Here may be mentioned the occurrence at Joachimstal, Bohemia, which Ulrich (20) established on the basis of optical measurements, and the occurrence in the Val Malenco, Lombardy, which was said by Cavinato (4) to be of orthorhombic crystals and which conformed on analysis to the heptahydrate. The original occurrence at Cape Hortegal, Galicia, Spain, described by Casares (3) also appears definitely to be of morenosite. Analytical evidence alone is not very satisfactory since the point at issue is the distinction between the hexahydrate and the heptahydrate. The difference in water content is small (41.12 and 44.90 weight per cent water, respectively), and decisive results would be difficult to obtain ordinarily since the material commonly occurs as fibrous or fine-grained efflorescences and contains hydrous impurities, notably annabergite. There also is the probability that part at least of the seventh molecule of water can be lost without breakdown of the orthorhombic structure, as in the case of the isostructural compound $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ (epsomite).

In the course of the present work, morenosite was identified by its optical properties and *x*-ray powder diffraction pattern* as emerald-green crystals associated with minasragrite and retgersite on a specimen of patronite from Minasragra, Peru. The occurrence of morenosite at this locality has been remarked earlier by Schaller (16). The crystals were not suited for crystallographic measurement. The material is optically negative, with $n_X = 1.470$, $n_Y = 1.493$, $n_Z = 1.500$, $2V$ small and dispersion $r > v$. These data diverge slightly from those reported by Dufet (5) for the pure artificial salt: $n_X = 1.4693$, $n_Y = 1.4893$, $n_Z = 1.4923$ (for Na) with $2V = 41^\circ 54'$ (meas.) and $r > v$. A spectrographic examination revealed the presence of V in an amount of the order of a few tenths of a per cent.

On standing in the open in dry air, crystals of morenosite generally dehydrate rapidly to the tetragonal hexahydrate, retgersite. This was verified by the writers on several artificial preparations. The product formed, however, varies considerably with circumstances. One artificial preparation, crystallized from a water solution containing a little HCl, proved to be stable under ordinary conditions. Further, the natural morenosite from Minasragra had partially effloresced during the thirty years or so that it had been contained in the collection, but the dehydration product

* X-ray powder data for the hydrated nickel sulfates are given by Hammel (9), in the *ASTM* card file, and for $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ by Borghijs (2).

proved to be not the hexahydrate but a mixture of several lower hydrates. Morenosite does not lose water if it is kept in a sealed, tightly packed container. It may be noted that orthorhombic $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ (epsomite), with which morenosite is isostructural, dehydrates to the monoclinic polymorph of $\text{MgSO}_4 \cdot 6\text{H}_2\text{O}$ (hexahydrate) and not to the tetragonal phase as in the case of morenosite. The tetragonal phase of $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ retgersite, apparently is stable in dry air at room temperature. Finely ground artificial preparations did not lose weight on standing in the open air for a period of weeks. A few large crystals of this substance that had been exposed to direct sunlight were observed to break down very slowly to a yellow-green product, probably $\text{NiSO}_4 \cdot \text{H}_2\text{O}$. The decomposition began at a few isolated spots, and the areas of the yellow green substance were rimmed by an intermediate zone of a pale bluish green material probably consisting of $\text{NiSO}_4 \cdot 2\text{H}_2\text{O}$.

REFERENCES

1. BEEVERS, C. A., AND LIPSON, H., *Zeit. Kryst.*, **83**, 123 (1932).
2. BORGHIS, L., *Natuurwet. Tijdschr.*, **19**, 115 (1937).
3. CASARES, D. A., cited by ALCIBAR, A. M., *Revista Minera*, Madrid, 176 (1851).
4. CAVINATO, A., *Atti R. Accad. Lincei, Rend.*, Cl. Sci., Rome, ser. 6, **25**, 399 (1937).
5. DUFET, H., *Compt. rend.*, **86**, 880 (1878) and *Bull. Soc. Min.*, **1**, 58 (1878).
6. FERGUSON, H. G., *Univ. Nevada Bull.*, **33**, No. 5 (1939).
7. GOSSNER, B., *Ber. deutsch. Chem. Ges.*, **40**, 2374 (1907).
8. GROTH, P., *Chemische Kryst.*, **2**, 423, 426, 428 (1908).
9. HAMMEL, F., *Ann. Chim.*, ser. 11, **11**, 247 (1939).
10. HUTTON, C. O., *Am. Mineral.*, **32**, 553 (1947).
11. LASPEYRES, H., *Verhandl. naturhist. Ver. Bonn*, **50**, 255 (1893). See also HUDSON, F. S., *Bull. Univ. Calif. Dept. Geol.*, **13**, 175 (1922); JOHNSTON, R. A. A., *Canada Dept. Mines, Geol. Surv.*, Mem. **74**, 162 (1915); HINTZE, C., *Handbuch der Min.*, **1**, Pt. 3B, 4354 (1929); and COLEMAN, A. P., *Canada Dept. Mines, Mines Branch*, Rept. **170** (1913).
12. MELLOR, J. W., *A Comp. Treatise on Inorg. Chem.*, **15**, 453 (1936).
13. PASCAL, P., *Traité de Chim. Min.*, **10**, 155 (1935).
14. ROHMER, R., *Ann. Chim.*, ser. 11, **11**, 611 (1939).
15. SCACCHI, A., *Atti R. Accad. Sci. Napoli*, **1**, no. 11 (1863).
16. SCHALLER, W. T., *J. Wash. Acad. Sci.*, **7**, 501 (1917).
17. SEIDELL, A., *Solubilities of Inorg. Compounds*, New York, 3rd ed., 1347 (1940); also STEELE, B. D. and JOHNSON, F. M. G., *J. Chem. Soc. London*, **85**, 116 (1904).
18. TOPSØE, H. F. A., *Archiv. sci. phys. nat. Geneve*, ser. 2, **45**, 223 (1872).
19. TOPSØE, H. F. A., AND CHRISTIANSEN, C., *Ann. Chim. Phys.*, ser. 5, **1**, 63 (1874).
20. ULRICH, F., *Casopis Musea Ceskeho*, Prague, **95**, 123 (1921).
21. VOLGER, G. H. O., *Jahrb. Min.*, 152 (1855).
22. VON KOBELL, F., *J. prakt. Chem.*, **58**, 44 (1853).

THERMAL STUDY OF RHODOCHROSITE

J. LAURENCE KULP, HAROLD D. WRIGHT, AND RALPH J. HOLMES
Columbia University, New York, New York.

CONTENTS

Abstract.....	195
I. Introduction.....	195
II. Experimental Equipment and Procedure.....	196
A. General Method.....	196
B. Apparatus.....	196
C. Procedure.....	197
D. Exothermic Peak Reproducibility.....	198
III. Substitution in Rhodochrosite.....	201
IV. Thermal Curves of Rhodochrosite-Carbonate Mixtures.....	202
V. Thermal Curves of Rhodochrosite.....	208
A. General.....	208
B. Discussion of Individual Curves.....	209
C. Type Thermal Curve for Rhodochrosite.....	214
D. Manganocalcite.....	215
VI. Conclusions.....	217
Bibliography.....	218

ABSTRACT

Representative specimens of rhodochrosite from many localities have been examined by the method of differential thermal analysis in order to establish the form and variations of the thermal curve of the mineral, and to study the effect of cation substitution on its thermal behavior. The optimum conditions of sample and apparatus providing reproducible thermal curves for this mineral group are discussed.

The endothermic peak was found to reproduce more consistently than the exothermic, varying from 609° C. to 724° C. but only one specimen gave an endothermic peak higher than 667° C. The majority range from 609° C. to 635° C. The temperature at which the endothermic peak occurs is raised by the presence of Ca and Mg and is lowered if iron substitutes for manganese in the lattice.

The materials used in the thermal work were checked by means of powder α -ray patterns and semi-quantitative tests for the cations in question.

Several specimens of manganocalcite varying widely in manganese content indicate that the substitution of Mn for Ca in the series calcite-rhodochrosite is probably continuous and unlimited.

I. INTRODUCTION

The members of many mineral groups may be distinguished by the method of differential thermal analysis since the temperatures at which reactions involving appreciable energy changes take place differ for the several members of the group. The relations between crystal structure and the stability of minerals with increasing temperature have been recognized by structural chemists and mineralogists for over 60 years but it is only within the last decade that these have been utilized as a practical aid in the identification and study of minerals.

The most extensive applications of differential thermal analysis have been in the field of clay mineralogy (Grim and Rowland, 1942), (Speil, Berkelhamer, Pask, and Davies, 1945), (Kerr and Kulp, 1947, 1948). Reconnaissance studies indicate the usefulness of the technique in the investigation of such mineral groups as the hydrous oxides, sulfates, phosphates, zeolites, and carbonates.

Little is known concerning the thermal behavior of the minerals of the carbonate group and even less about the influence on the thermal curves of ionic substitution among the cations of this group. The present investigation attempts to define the type thermal curve of rhodochrosite and its variations in order to study the extent of cation substitution in rhodochrosite as indicated by correlated thermal, x-ray and chemical data.

The authors are especially indebted to Prof. Paul F. Kerr, at whose suggestion the problem was undertaken. His helpful advice and critical reading of the manuscript are greatly appreciated. They also wish to thank Professor Charles H. Behre, Jr., with whom certain aspects of the paper were discussed. Dr. Frederick H. Pough, Curator of Mineralogy, American Museum of Natural History, made available several specimens of manganocalcite which added much to the study.

II. EXPERIMENTAL EQUIPMENT AND PROCEDURE

A. General Method. Many minerals when heated at a constant rate to about 1000° C. undergo thermal reactions (gain or loss of heat) due to (1) loss of either absorbed or lattice (OH) water, (2) chemical combination, (3) decomposition, or (4) changes in crystal structure. The reactions usually are characteristic of a given mineral, and thus may be used for identification. Further, since the intensity of reaction is roughly proportional to concentration, a quantitative estimate of the proportions of the component minerals in mechanical mixtures can be obtained.

In practice the thermal properties of a mineral are detected by comparing its temperature with that of an inert material as both are heated at the same constant rate. One terminal of a two-headed thermocouple is placed in the mineral, the other in the inert material (alundum). Voltage across the terminals of the pair is detected only when there is a difference in temperature between them. If the temperature differential is plotted against the temperature of the inert material, thermal reactions of the mineral appear as exothermic or endothermic peaks on an otherwise straight line curve. The shape and temperature position of these peaks usually are characteristic of a particular mineral, and can be readily measured and studied. (For details of method see Spiel et al., 1945 and Kerr and Kulp, 1948.)

B. Apparatus. The apparatus used was the multiple thermal analysis

unit in the Mineralogical Laboratory of the Department of Geology, Columbia University. Both apparatus and technique are fully described elsewhere (Kerr and Kulp, 1948). X-ray diffraction equipment using iron radiation was employed in obtaining Debye powder patterns.

C. Procedure. The specimens studied were obtained from the Mineralogical collection of Columbia University, except for certain mangano-calcites obtained from the American Museum of Natural History. Specimens from the following localities were made use of:

Locality	No. of specimens sampled
Lake County, Colorado	3
Saguache County, Colorado	1
Park County, Colorado	1
Austin, Nevada	1
Branchville, Connecticut	1
Cummington, Massachusetts	1
Butte, Montana (various mines)	3
Whitehall, Montana	1
Stassfurt, Germany	1
Staffel, Bavaria	1
Oberneisen, Nassau	1
Lahnstein, Prussia	1
Franklin, New Jersey	6

A preliminary study of the influence of fragment size on the thermal curve was made by separating fractions of four different size ranges and testing them simultaneously in the thermal apparatus. The fragment sizes used were: (1) 50–80 mesh; (2) 80–120 mesh; (3) 120–200 mesh; and (4) minus 200 mesh. No appreciable change was observed in the shape of the thermal curves, but the endothermic peak temperature varied slightly with fragment size. The differences in peak temperatures given by (80–120) and (120–200) mesh fragments were negligible. The endothermic peak temperatures of the (50–80) mesh fraction was about 5° C. above the average for the (80–200) mesh range, and fragments which passed 200 mesh had an endothermic peak about 5° C. below. Therefore preparation procedure was standardized so that only (80–200) mesh fragments were used for the thermal analysis work. The samples were heated to 1000° C. at a near-constant rate of 12° C. per minute.

Qualitative and semi-quantitative chemical tests for Ca, Mg, Mn and Fe, and x-ray powder patterns (Debye) were obtained for all samples and each sample was examined with the aid of a petrographic microscope for impurities.

Shifts in the endothermic peak temperatures were correlated with corresponding shifts in the high angle lines of the x-ray powder patterns,

and with the evidence of substitution of Ca^{++} , Mg^{++} and Fe^{++} for Mn^{++} in the crystal lattice indicated by the results of the chemical analyses.

A quantitative study of the effects of impurities on the thermal curve of rhodochrosite was made using artificially prepared mixtures of rhodochrosite with calcite, dolomite, siderite and chemically pure CaCO_3 powder. The shift in endothermic peak temperature, and the relation between area under the curve and percentage of a given constituent were investigated.

D. Exothermic Peak Reproducibility. Experimental work indicated that the exothermic (oxidation) peak which follows the large endothermic decomposition reaction varies considerably in shape and peak temperature, while the endothermic peak remains reasonably constant. (The endothermic and exothermic reactions will be discussed more fully later.) In most cases the exothermic peak appears as a long, low arch rather than a sharp, pointed peak, like that produced by the endothermic reaction. This exothermic reaction is believed to be a result of air oxidation of the lower valence manganese oxide produced in the decomposition of rhodochrosite, and in the furnace it was evident that something inhibited the immediate oxidation of the decomposition product, manganous oxide. An attempt was made to obtain a reproducible exothermic peak by varying (1) the fragment size and (2) the position of the cover disc. A rhodochrosite specimen* from the Anaconda Mine, Butte, Montana, was selected for the exothermic peak study. Experiments were made under the following conditions:

- (1) Minus 80 mesh fragments; cover on.
- (2) Same.
- (3) Minus 50 plus 120 mesh fragments; cover off.
- (4) Minus 50 plus 120 mesh fragments; cover on.
- (5) Minus 80 plus 200 mesh fragments; cover off.

These experiments demonstrate that particle size is not a critical factor in obtaining reproducible exothermic peaks. It is clear, however, that the cover disc had restricted the free access of oxygen to the rhodochrosite decomposition product. When the cover was removed the curves showed sharp exothermic peaks which are largely reproducible from one experiment to the next. The remaining differences in exothermic peak shape are to be attributed to the thermocouple position and the nature of the weld. The curves in Figs. 1 and 2 illustrate the results obtained in the five experiments listed above. Those of Fig. 1 were obtained with the cover on. The peak due to the oxidation reaction is not appreciably developed and

* The double endothermic peak indicates an intergrowth of two rhodochrosites which differ in the foreign cations substituted for Mn in the lattice. This specimen is discussed in detail later.

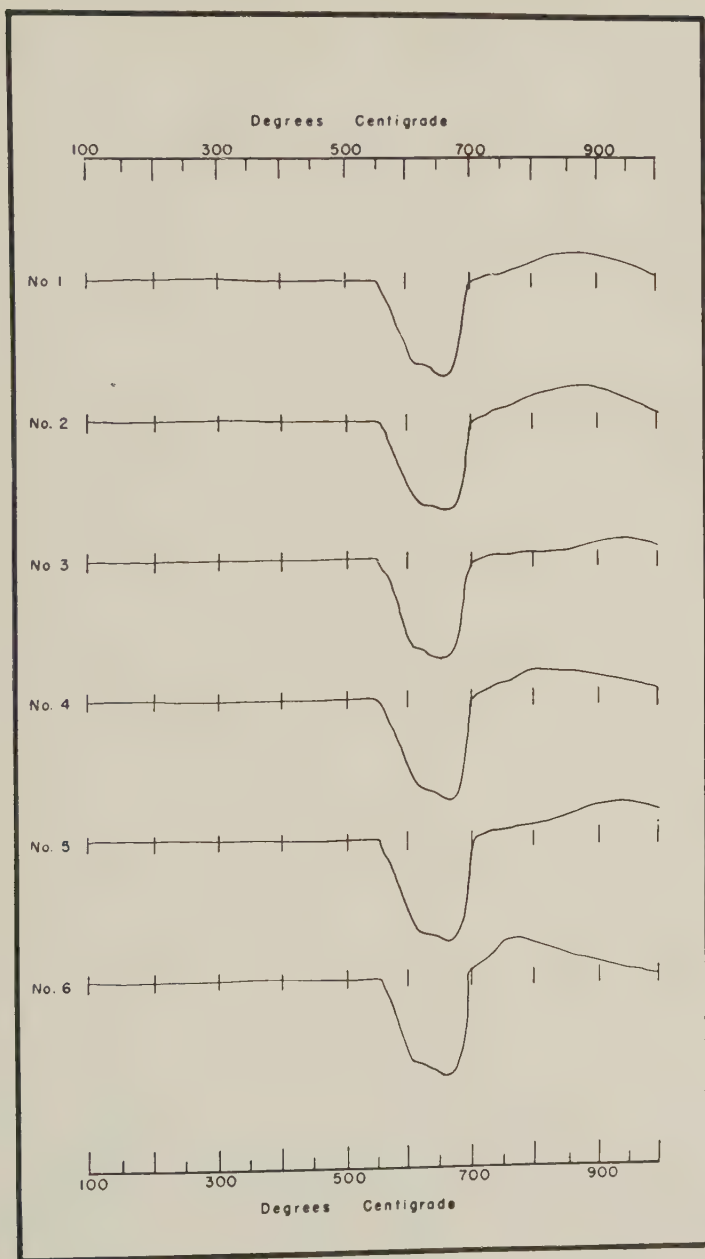


FIG. 1. Exothermic Peak Study. Cover on, restricting free access of air to sample. (50-120 mesh fragments.)

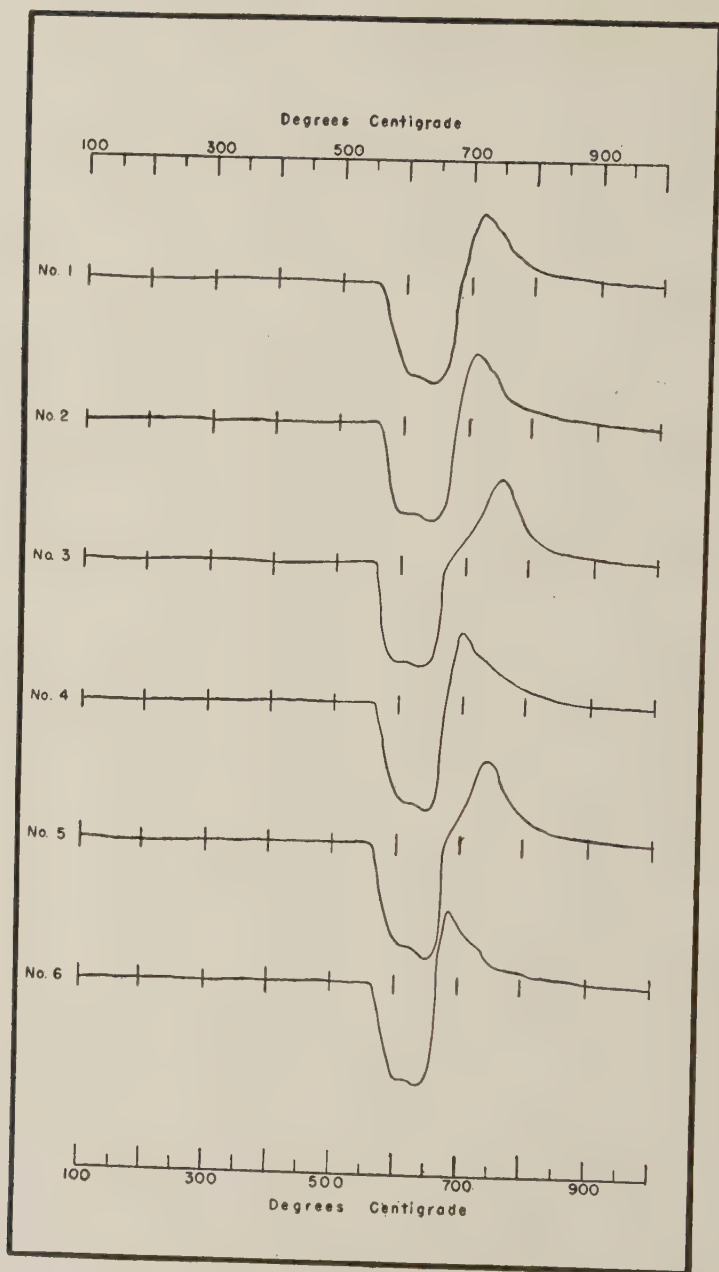


FIG. 2. Exothermic Peak Study. Cover off, permitting free access of air to sample for oxidation. (50-120 mesh fragments.)

there is little relation among the individual curves. These were not reproducible from one experiment to the next. The curves in Fig. 2, on the other hand, show the sharp exothermic peak produced by removing the cover. Under these conditions the peaks are reproducible for a particular thermocouple in successive experiments, but the curves obtained for different thermocouples during the same experiment differ somewhat due to differences in position of the thermocouple head. Curves Nos. 3 and 5 exhibit a delayed peak because the thermocouple head was considerably below the center of the sample.

From this study it is evident that reproducible thermal curves of rhodochrosite or other minerals that undergo air oxidation could not be obtained with the sample holder cover in place. Accordingly, a special cover was made with small supports, which leaves about $\frac{1}{8}$ " space between cover and sample holder. This permits free access of oxygen to the samples but shields them from direct furnace radiation. This innovation was used for all of the subsequent thermal curves discussed in this paper.

III. SUBSTITUTION IN RHODOCHROSITE

The mutual substitution of the common divalent metallic ions in the carbonate minerals is tacitly assumed in most mineralogical texts. An examination of the ionic radii of Ca^{++} , Mg^{++} , Fe^{++} and Mn^{++} in relation to the crystal structure of the carbonates indicates that such substitution seems possible. The clearest demonstration of this phenomenon was provided by the work of Krieger (1930), who showed that in manganoan calcite Mn^{++} can substitute for Ca^{++} to at least 40%. He demonstrated that this substitution may be correlated with a linear shift in the indices of refraction, specific gravities and the position of the lines in the x -ray diffraction patterns.

The present investigation provides further evidence of this phenomenon in the case of the substitution of Ca^{++} , Mg^{++} , and Fe^{++} for Mn^{++} in rhodochrosite. This is particularly interesting since the temperature of decomposition is necessarily related directly to the bonding energies in the lattice. Since the shift in peak temperature on a thermal curve is more pronounced than the corresponding shift in the high angle lines of the x -ray pattern, differential thermal analysis is an expeditious technique for detecting this phenomenon. This is particularly true of carbonates that contain more than 60% "impurity."

If a single carbonate ion surrounded by its nearest neighbor cations is considered, it is evident that the temperature of decomposition will be directly dependent upon the strength of the cation-carbonate bond. Decomposition will occur at the temperature at which the internal energy of the carbonate ion just exceeds the bonding energy, thus freeing the CO_2

molecule. Further, the cation-carbonate bonds progress in strength from siderite through rhodochrosite and magnesite to calcite, since each succeeding mineral has a higher decomposition temperature.

This is illustrated by comparing the thermal behavior of magnesite and dolomite (Faust, 1944). Magnesite decomposes with a single exothermic peak into periclase (MgO). The temperature of the lower endothermic peak of dolomite is about a hundred degrees above that of magnesite and is due to the decomposition of dolomite into periclase and fine calcite. The carbonate ion most closely associated with the magnesium ion in the dolomite lattice, therefore, due to the calcium-carbonate bonds, has additional stability over the carbonate ion in magnesite.

From this it follows that the random substitution of calcium or magnesium ions for manganese ions in the rhodochrosite lattice will strengthen the cation-carbonate bond and thereby increase the decomposition temperature. Furthermore, since the lattice is sufficiently open to allow substitution of calcium for manganese ions without introducing appreciable strain, a continuous shift of decomposition temperature from pure rhodochrosite to pure calcite is to be expected. In the present study, endothermic peak shifts indicate substitution of calcium for manganese ions to the extent of approximately 40%. Further, a specimen of mangano-calcite from Franklin, New Jersey, which probably contains about 10% Mn^{++} in Ca^{++} positions (estimate based on shift in x -ray diffraction lines compared with patterns obtained by Krieger on analyzed material) showed a shift of about 30° downward in the endothermic peak temperature. By analogy, specimens in which iron has substituted for manganese will show lowered endothermic peak temperatures, and magnesium for manganese substitution likewise will result in raised peak temperatures. Such substitution in the natural rhodochrosite specimens has been observed by means of shifts both in x -ray diffraction lines and peaks in thermal curves.

A tabulation of data on a selected group of rhodochrosite-mangano-calcite specimens illustrating this substitution phenomena is given in Table 1. The shift in x -ray diffraction lines is consistent with the chemical and thermal data. With increasing Ca^{++} substitution, the thermal curve peaks are shifted upward in temperature and the x -ray lines move from the rhodochrosite to the calcite positions.

IV. THERMAL CURVES OF RHODOCHROSITE-CARBONATE MIXTURES

Artificially prepared mixtures of rhodochrosite with other carbonates were tested thermally in order to study the extent to which the percentage composition of naturally occurring intergrowths of rhodochrosite with other carbonates could be determined by means of differential

TABLE 1

Specimen	Approximate cation composition*				Endo- thermic peak tempera- ture	“d” outer- most strong α_1 line
	Ca ⁺⁺	Mg ⁺⁺	Fe ⁺⁺	Mn ⁺⁺		
(Ideal rhodochrosite)	—	—	—	(100%)	(615° C.)	—
Oberneisen, Nassau	—	Trace	—	100%	615° C.	1.001
Butte, Mont. #2	5–10%	—	10%	80%	640° C.	1.000
Butte, Mont. #1 (2nd peak)	10–15%	—	5%	75%	660° C.	1.001
Whitehall, Mont.	15–20%	—	5%	75%	670° C.	1.003
Cummington, Mass.	30%	—	—	70%	730° C.	1.017
Franklin, N. J.	90%	—	—	5–10%	935° C.	1.024
(manganocalcite #5)						
(Iceland spar)	100%	—	—	—	990° C.	1.045

* Determined by semi-quantitative semi-micro methods using known mixtures as standards. The error is estimated to be $\pm 5\%$ below 30% and $\pm 10\%$ above 70%.

thermal analysis. The resulting thermal curves are reproduced in Figs. 3, 4, and 5.

Figure 3 shows the curves obtained from mixtures of Lake County, Colorado, rhodochrosite (80–200) mesh with chemically pure calcium carbonate powder.

- #1 90% MnCO_3 –10% CaCO_3
- #2 75% MnCO_3 –25% CaCO_3
- #3 60% MnCO_3 –40% CaCO_3
- #4 40% MnCO_3 –60% CaCO_3
- #5 25% MnCO_3 –75% CaCO_3
- #6 10% MnCO_3 –90% CaCO_3

The endothermic peak temperature lowered progressively from 592° C. with 90% MnCO_3 to 550° C. with 25% MnCO_3 . The peak temperature decreased more rapidly in the low MnCO_3 range than in the high. The lowering effect of impurity on the endothermic peak temperature may be seen equally well in the case of the CaCO_3 peak.

No rhodochrosite peak was obtained for the 10% MnCO_3 –90% CaCO_3 mixture, yet an appreciable CaCO_3 peak occurred for the mixture with 10% CaCO_3 . (See curve #6.) The explanation of this appears to be quite simple. Similar phenomena have been observed with siderite ground to the same fragment size (80–200 mesh). When the rhodochrosite is diluted to the point where the oxygen in the air spaces immediately surrounding a rhodochrosite fragment is sufficient to oxidize completely the

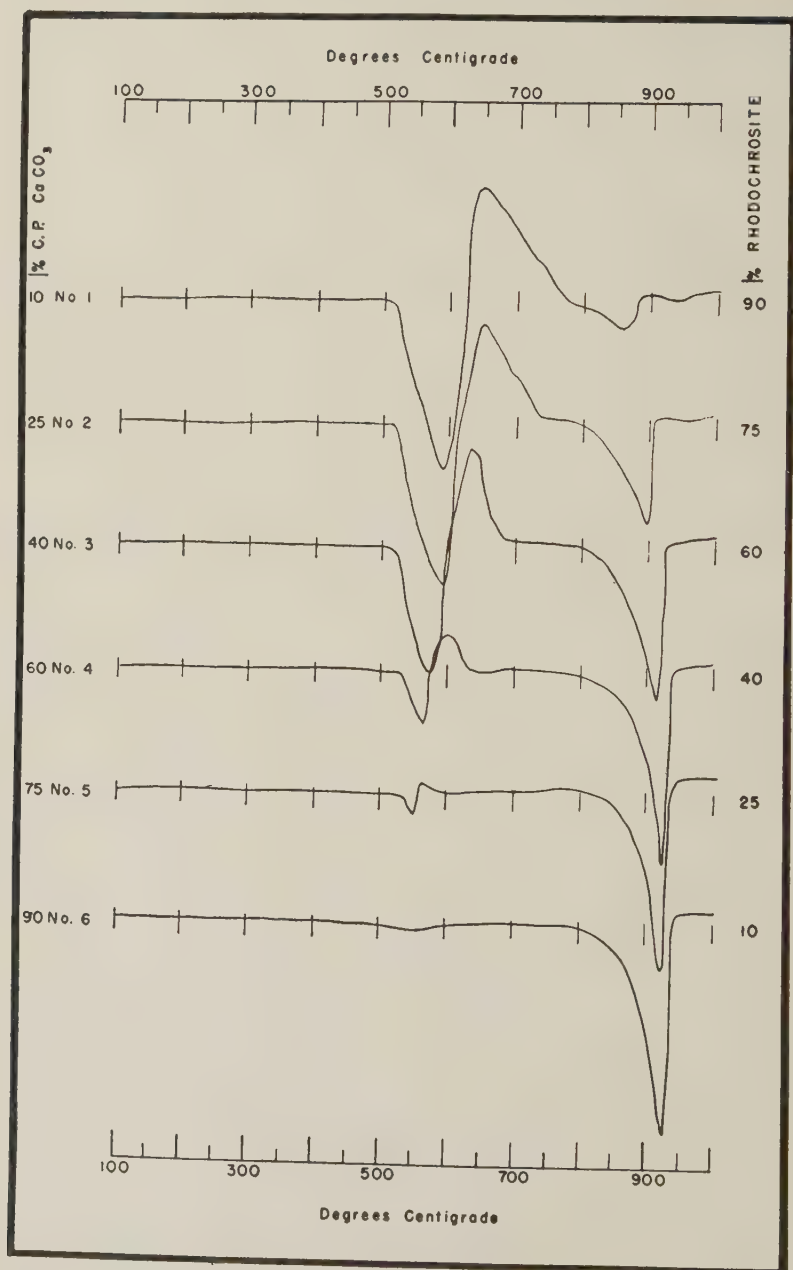


FIG. 3. Differential Thermal Curves of Mixtures of Rhodochrosite with C.P. Calcium Carbonate.

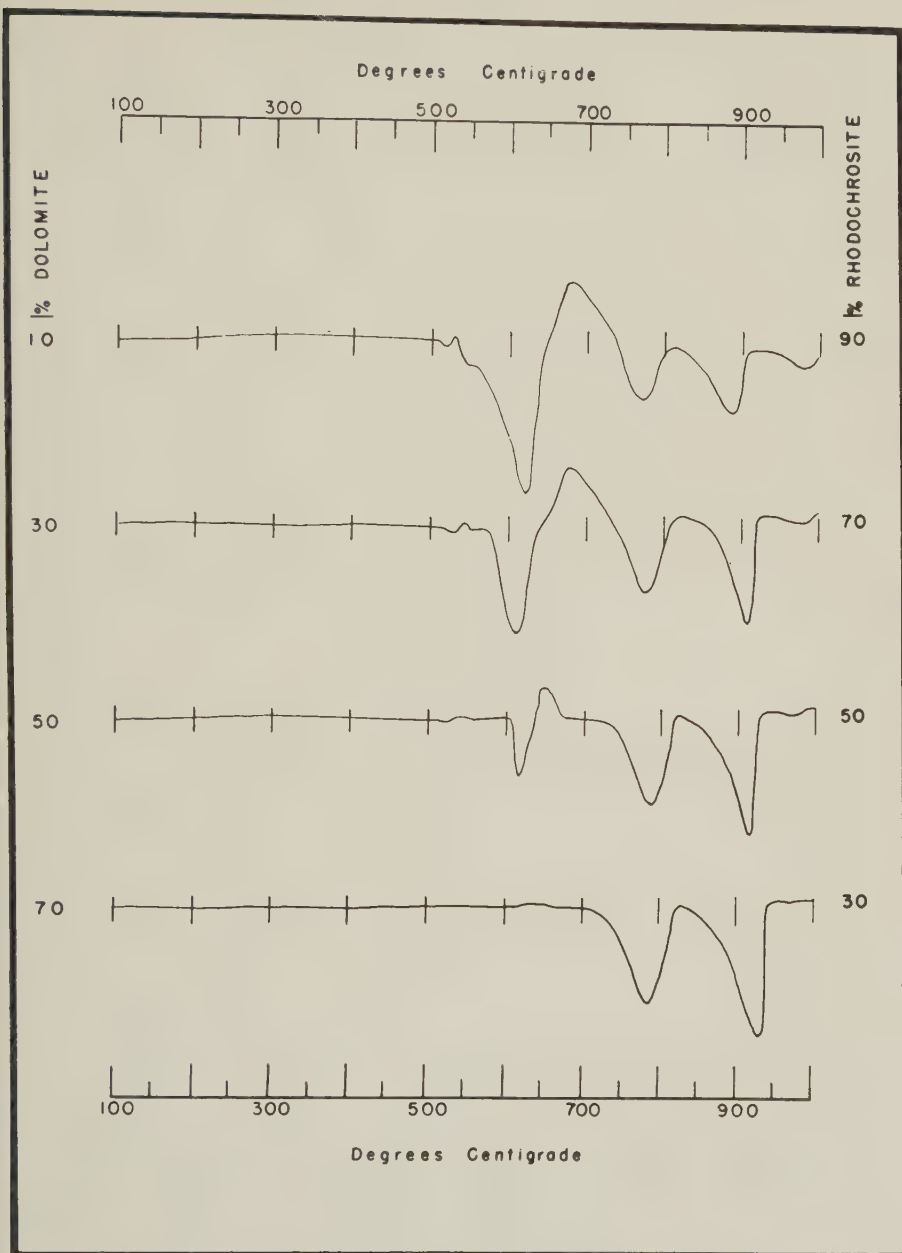


FIG. 4. Differential Thermal Curves of Mixtures of Rhodochrosite with Dolomite.

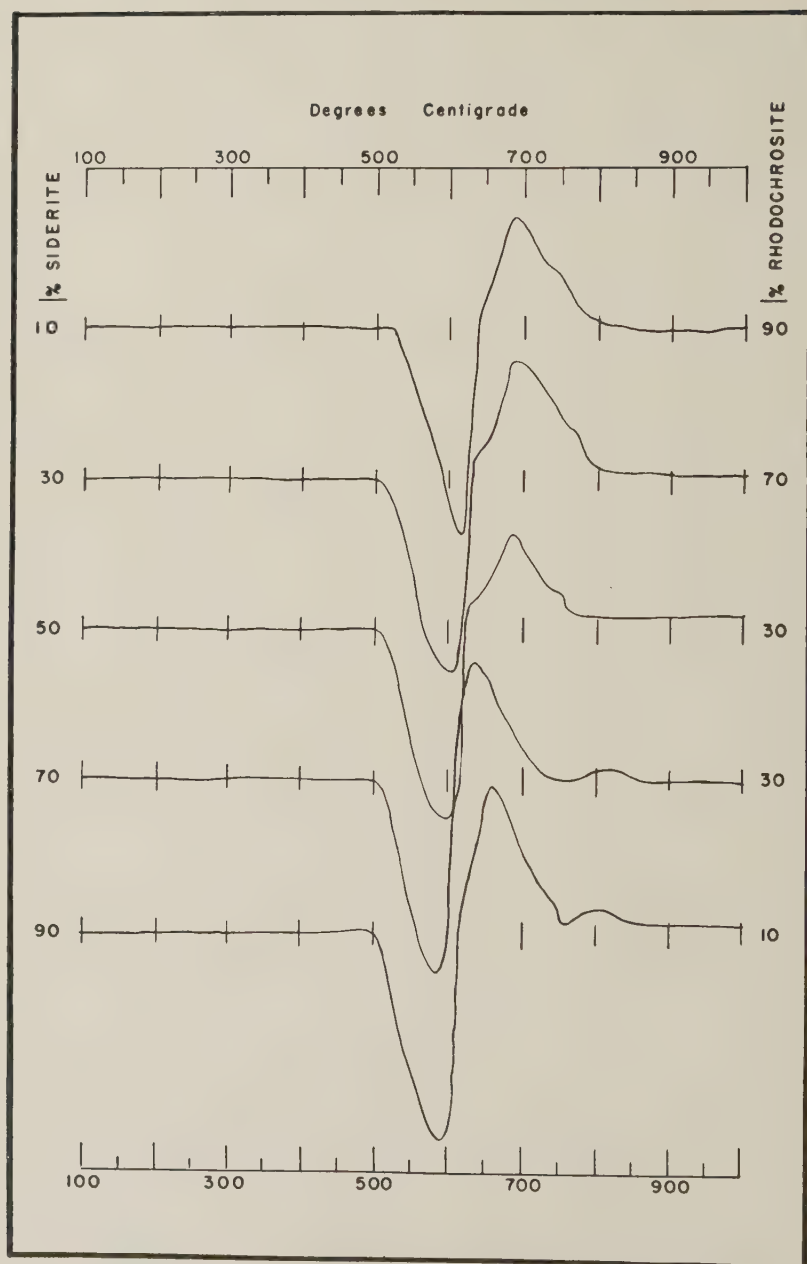


FIG. 5. Differential Thermal Curves of Mixtures of Rhodochrosite with Siderite.

MnO formed from its decomposition, the oxidation reaction immediately follows the decomposition. Since the energy changes involved in both processes are about equal but in opposite directions, the effects cancel out and the thermal curve shows no peaks. Presumably, if the thermal analysis of a 10% rhodochrosite sample were run in an atmosphere of CO_2 , an endothermic peak with the appropriate amplitude would be observed. This effect should vary with the nature of the foreign constituent and the particle size.

The slight endothermic peak at $940^\circ\text{--}950^\circ\text{C.}$ in curves #1 and #2 is the same as that appearing in the Lake County #1 curve, Fig. 6.

A similar series of mixtures with Iceland spar ground to 200 mesh gave analogous results. The most striking difference is the fact that the extremely fine CaCO_3 powder (chemical precipitate) gives an endothermic peak at 938°C. as compared to 950°C. for Iceland spar ground to 200 mesh in 90% calcite mixture.

The curves obtained from the mixture of Lake County rhodochrosite with Oberdorf, Styria, dolomite are grouped in Fig. 4.

- #1 90% MnCO_3 —10% $\text{Ca, Mg}(\text{CO}_3)$
- #2 70% MnCO_3 —30% $\text{Ca, Mg}(\text{CO}_3)$
- #3 50% MnCO_3 —50% $\text{Ca, Mg}(\text{CO}_3)$
- #4 30% MnCO_3 —70% $\text{Ca, Mg}(\text{CO}_3)$

The rhodochrosite endothermic peak shifts from 620°C. for 90% MnCO_3 to 613°C. for 50% MnCO_3 . In the 30% rhodochrosite mixture no appreciable rhodochrosite peak appeared for reasons given above. The upper dolomite peak shifts from 885°C. for the 10% dolomite mixture to 930°C. for 70% dolomite, whereas the lower dolomite peak temperature increases only about 20°C. with increasing concentration in the same range. The small endothermic and exothermic dips occurring at $500^\circ\text{--}550^\circ\text{C.}$ in the first three curves are due to an impurity in the rhodochrosite used. The specimen was from Lake County, Colorado, as was that used for the CaCO_3 mixtures, but probably contained more FeCO_3 . The small endothermic dip occurring at 980°C. is probably the same as that found in the MnCO_3 — CaCO_3 mixture runs, and is believed due to an unidentified impurity in the rhodochrosite.

MnCO_3 — FeCO_3 Mixtures. The curves for mixtures of Lake County rhodochrosite with Roxbury, Connecticut, siderite are reproduced in Fig. 5.

- #1 90% MnCO_3 —10% FeCO_3
- #2 70% MnCO_3 —30% FeCO_3
- #3 50% MnCO_3 —50% FeCO_3
- #4 30% MnCO_3 —70% FeCO_3
- #5 10% MnCO_3 —90% FeCO_3

The thermal curve of siderite is the most similar to that of rhodochrosite of all the carbonate curves. (This is to be expected from the close similarity in ionic radii and lattice constants.) The endothermic peak of the siderite curve occurs about 50° C. lower than that of rhodochrosite.

Because the shapes of the curves and the peak temperatures are so closely similar for the two components, the result is a blending of the two with only a suggestion of two peaks where the percentages of the two components are approximately equal. Curves #2, #3, and #4, Fig. 5, show considerable broadening near the peak. A progressive lowering of peak temperature from 615° C. with 90% rhodochrosite to 591° C. with 90% siderite is seen. The exothermic bulge at about 810° C. in #4 and #5 is due to an unidentified impurity in the siderite. The exothermic peak follows the downward trend with the endothermic peak.

In summary, mixtures of rhodochrosite with other carbonates produce thermal curves which show the following general characteristics:

- (1) "Mixture" curves are a combination of the curves typical of each component.
- (2) The greater the amount of impurity present, the lower the temperature at which the endothermic (and generally the exothermic) peak occurs (Kerr and Kulp, 1947).
- (3) The lowering of the endothermic peak temperature is not a linear function of the amount of impurity present, but is greater for a given change in amount of impurity where the amount of impurity is large, than for the same change where the amount of impurity is small.
- (4) The area under the endothermic or exothermic peak is roughly proportional to the amount of the constituent producing this peak (Kerr and Kulp, 1947).

V. THERMAL CURVES OF RHODOCHROSITE

A. General. For the rhodochrosite specimens tested, a range in endothermic peak temperature of 609° C. to 724° C. was found, but only one specimen showed a peak temperature higher than 667° C. Considerable variation in exothermic peak temperature was observed, which was not surprising in view of the variability of conditions affecting the exothermic reaction, discussed previously.

Variations in the endothermic peak temperature are traceable to two major factors: (1) replacement of Mn^{++} by other cations such as Fe^{++} , Ca^{++} and Mg^{++} in the crystal lattice, and (2) the presence of thermally active or inactive impurities.* As pointed out earlier, substitution may elevate the endothermic peak temperature, as in the case of the Mg^{++} and Ca^{++} ions, or lower the peak temperature, as with the Fe^{++} ion. It has been shown by other workers (Kerr and Kulp, 1947), (Speil, Berkel-

* Throughout this discussion the term "impurities" will refer to mechanically admixed foreign constituents in the rhodochrosite specimens, not to cations substituting in the rhodochrosite lattice.

hamer, Pask and Davies, 1945), (Cuthbert and Rowland, 1947) that the presence of impurities invariably results in a lowering of endothermic peak temperatures. The difficulties in duplicating conditions of packing and maintaining thermocouple head sensitivity and geometry, impose a limit of error which probably does not exceed $\pm 5^{\circ}$ C. in peak temperature.

B. Discussion of Individual Curves. Figures 6 and 7 show the thermal curves for the most interesting and typical rhodochrosites. They will be discussed successively in the following section.

Lake County, Colorado.

The three specimens tested yielded endothermic peaks of similar shape and amplitude, with the peak temperatures spread over a relatively small range, 8° C. Fe^{++} was found in appreciable quantity (estimated 10–30% of cations) by qualitative chemical analysis. The double exothermic peak of #3 cannot be satisfactorily explained at present. It may be due to the formation and decomposition of an Fe-Mn oxide complex. The endothermic dip at about 850° C. in samples #2 and #3 is probably due to a small percentage of included calcite.

Saguache County, Colorado

This sample showed a double endothermic peak, with the lower peak at 652° C., the upper at 698° C. Even the lower of the twin peaks is at a temperature considerably higher (25° C. to 30° C.) than the peak temperatures of the Lake County samples, and the upper peak is well out of the general range found to be characteristic for rhodochrosite. Qualitative chemical analysis indicated the presence of Ca^{++} , Mg^{++} and Fe^{++} ions in appreciable quantities. It is estimated that Ca^{++} is the principal substitution ion in the Mn^{++} positions in the lattice, possibly to the extent of 25%. The double peak indicates an intergrowth of two rhodochrosites of different compositions. Ca^{++} and Mg^{++} substitutions are possible in both constituents, but Fe^{++} is probably prominent in the lower member. It is suggested that the lower member is at least a tricomponent rhodochrosite (Ca, Fe, Mn) while the higher member is at least a di-component (Ca, Mn) rhodochrosite. An intergrowth of two closely similar substituted rhodochrosites is also indicated by the abnormal line broadening apparent in the high angle lines of the x-ray patterns. The exothermic peak does not occur until the second rhodochrosite is decomposed due to the fact that the decompositions overlap and oxygen cannot readily get to the sample until the evolution of CO_2 has ceased.

Park County, Colorado

The curve is regular and indicates no appreciable impurity. The endothermic peak temperature of 664° C. is high for rhodochrosite. Qualitative chemical analysis showed, besides Fe, an appreciable amount of the

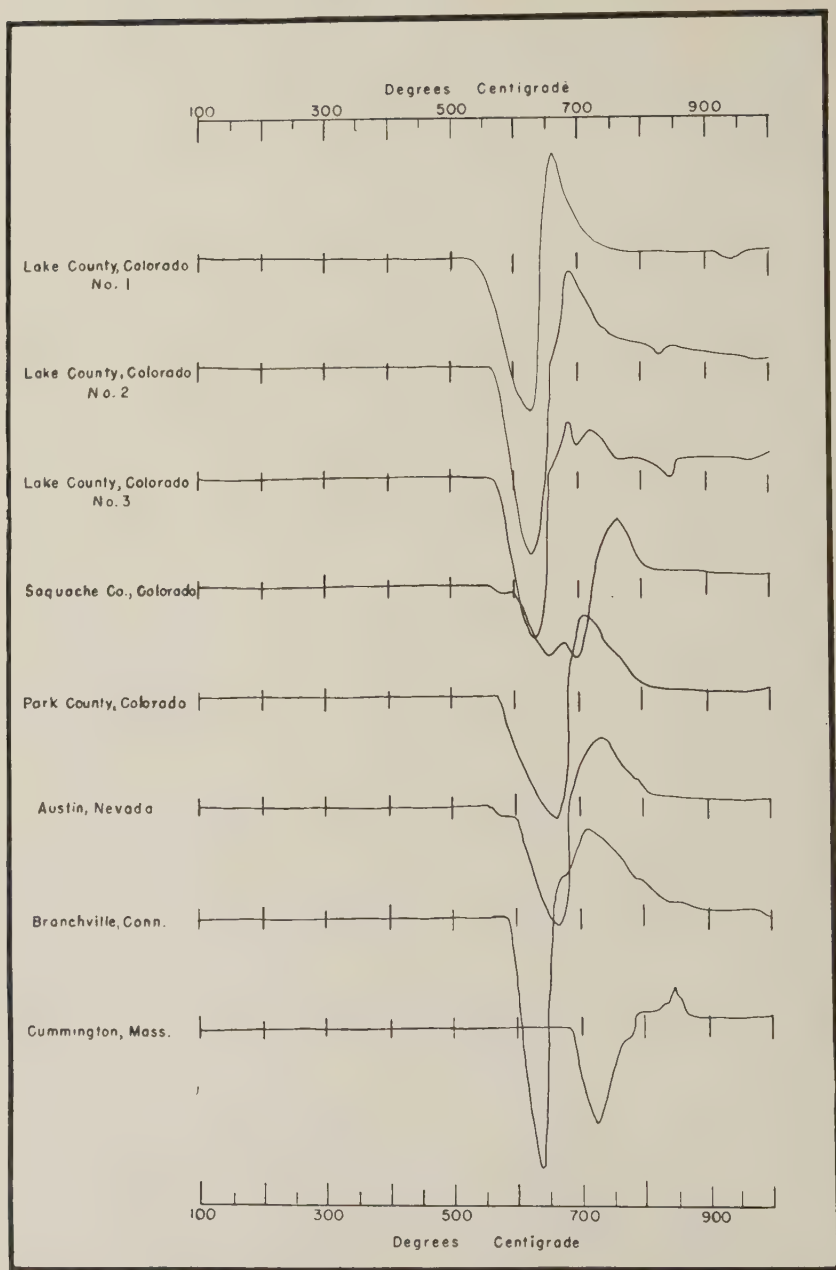


FIG. 6. Differential Thermal Curves of Rhodochrosite.
Specimens from various localities.

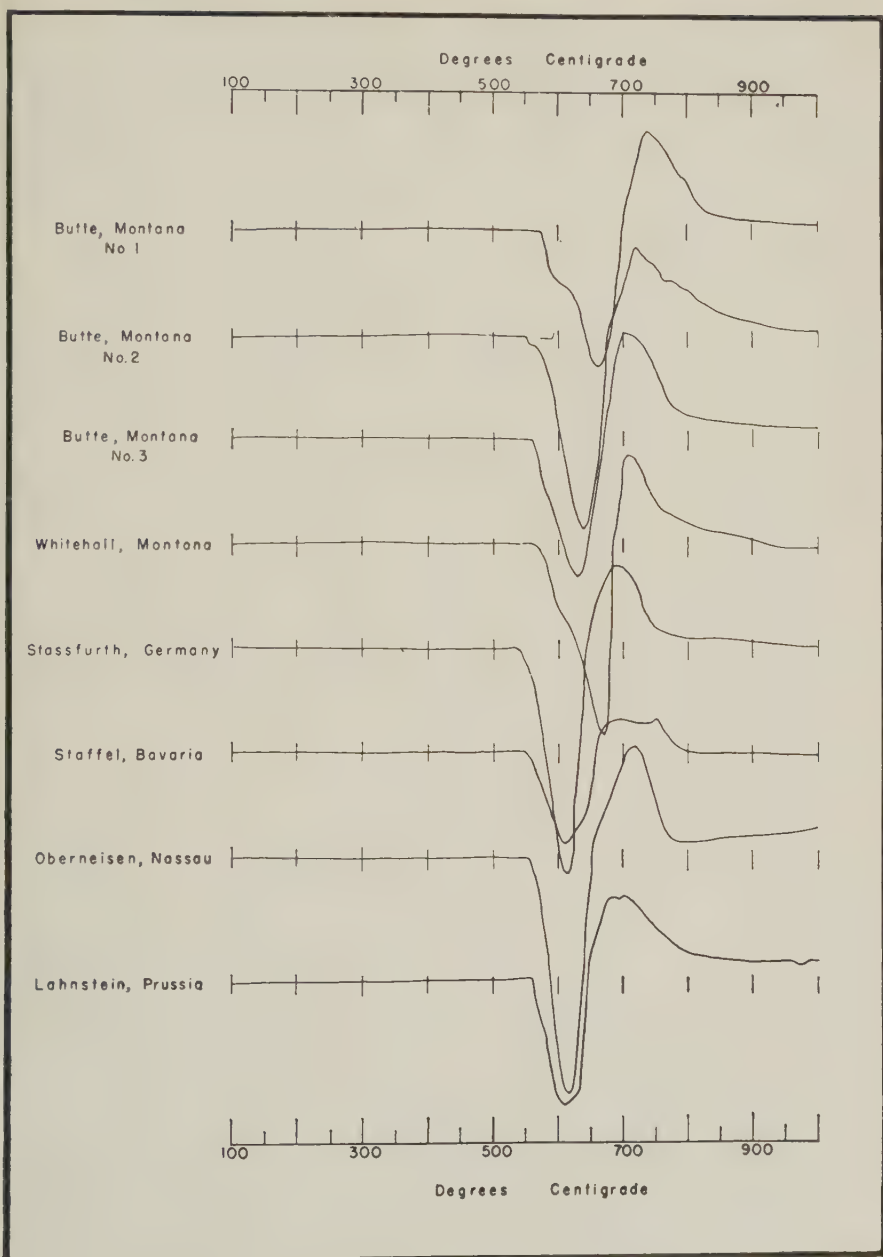


FIG. 7. Differential Thermal Curves of Rhodochrosite.
Specimens from various localities.

Mg⁺⁺ ion. Since there is no appreciable irregularity in the shape of the curve, the magnesium probably occupies manganese positions in the lattice, and this would account for the upward shift in endothermic peak temperature. On the basis of the absence of lines due to magnesite in the x-ray patterns it is believed that Mg⁺⁺ substitution in the rhodochrosite lattice is a more probable explanation of the chemical results than an intergrowth of magnesite and rhodochrosite.

Austin, Nevada

This curve is similar to that given by the Lake County sample in general shape and endothermic peak temperature, although the exothermic peak is not as sharp and occurs at a higher temperature. An endothermic dip occurs at approximately 575° C. and is possibly due to siderite impurity. Semi-quantitative analysis indicated the presence of calcium, representing about 10–20% of the cation positions in the lattice. This accounts for the high endothermic peak temperature (666° C.). Lines in the x-ray diffraction pattern are shifted toward calcite, but no siderite lines were detected.

Branchville, Connecticut

This material gave an exceedingly narrow, sharp endothermic peak, indicative of uniform grain size. No significant irregularities appear. Qualitative chemical analysis showed the presence of moderate Ca⁺⁺ and Fe⁺⁺, which probably substitute for manganese in the lattice. The endothermic peak is only slightly increased due to the counterbalancing effect of Fe⁺⁺ and Ca⁺⁺.

Cummington, Massachusetts

The curve produced by this material is remarkable for the high endothermic peak temperature, 724° C. Qualitative chemical analysis indicates that a large amount of Ca⁺⁺ (estimated 35%) is present; in fact more than in any of the other specimens tested. The high endothermic peak temperature indicates that the Ca⁺⁺ ion probably occupies Mn⁺⁺ lattice positions, representing approximately 35% of the total Mn⁺⁺ lattice positions. The small size of the exothermic peak may be attributed at least in part to Ca⁺⁺ for Mn⁺⁺ substitution, since the calcium oxide remaining after decomposition of calcium carbonate is not oxidized to a higher valence state of the cation as is manganous oxide (MnO). The smaller endothermic area may be attributed in part to the presence of inert impurities, whose presence was indicated by the fine-granular nature and brownish color of the material.

Butte (including Whitehall), Montana

The unusual breadth of the curve across the base line and the changes in slope along the lower temperature side of the endothermic part of the curve possibly reveal another case of two intimately intergrown rho-

dochrosites in the cases of the Butte #1 and Whitehall specimens. These were shown by qualitative analysis to have a strong Fe^{++} content and moderate Mg^{++} . It is suggested that the low temperature variety is (Fe-Mn) and the high temperature member (Mn-Mg). The presence of Fe^{++} was indicated for Butte #2 and #3. The Fe^{++} and Mg^{++} may be assumed to be present in the lattice rather than in an impurity since the thermal curve shows no appreciable irregularities.

The specimen used for the exothermic peak studies, Figs. 1 and 2, came from the Anaconda Mine, Butte, Montana. Instead of a single endothermic peak, a doublet is apparent. Since the area under the curve is essentially the same as the single peak rhodochrosites and the qualitative chemical analysis indicates moderate concentration of Fe^{++} and Mg^{++} as foreign cations, it seems probable that this specimen is an intimate intergrowth of Fe-rhodochrosite and Mg-rhodochrosite. This hypothesis is consistent with the mottled appearance of the specimen. The x-ray diffraction photograph shows abnormally broad lines, but only rhodochrosite lines. This is not the case in a diffraction pattern of a single rhodochrosite exhibiting substitution in its lattice. Further, a sample of this material was heated to 610°C . and cooled quickly. According to the explanation given above, this should have essentially decomposed the lower temperature Fe-rhodochrosite but left the higher temperature Mg-rhodochrosite. An x-ray diffraction pattern of the residue yielded the lines of hausmannite (the normal decomposition product of rhodochrosite) and sharp lines of rhodochrosite shifted slightly toward the low angle range of the film compared to those of Lake County rhodochrosite. The above hypothesis appears to account satisfactorily for this interesting rhodochrosite doublet.

The lower peak may be due to manganoan siderite rather than to ferroan rhodochrosite. However, the x-ray diffraction lines more closely approximate rhodochrosite than siderite.

Stassfurt

This curve approaches the ideal for rhodochrosite. The narrow, sharp endothermic peak occurs at 612°C ., and is followed by a typical exothermic peak with no irregularities. A trace of Mg^{++} as well as Fe^{++} appeared in the qualitative analysis but no effect can be seen on the thermal curve. This is to be expected for quantities of the substituting ions under 50%. When they occur as admixed impurities, the presence of even 5% is sometimes observable on the thermal curve as shown by the calcite in the Lake County specimen. On the basis of chemical and thermal analysis, this specimen appears to be the purest rhodochrosite studied.

Staffel, Bavaria

The peaks produced by this material are broad and of small amplitude.

The flat-topped exothermic peak is unusual and is believed to be due to the relatively lower position of the thermocouple in the sample holder used. The greater difficulty of penetration by oxygen may account for the broadening and flattening of the exothermic peak. Qualitative analysis indicated an appreciable amount of Fe^{++} .

Oberneisen, Nassau

Like the Stassfurt specimen, this material closely approximates the type curve. The sharp endothermic peak occurs at 616°C . and is followed by a relatively sharp exothermic peak. Qualitative analysis indicates appreciable Fe^{++} content, and a trace of Ca^{++} . The amount of the latter probably is too small to affect the curve.

Lahnstein, Prussia

The curve produced by this specimen shows an endothermic peak at 609°C . followed by an exothermic peak which is typical except for the slight endothermic dip at the peak. Another slight endothermic dip at about 975°C . cannot be accounted for by the qualitative chemical data, which shows only a trace of Ca^{++} but appreciable Fe^{++} content.

C. Type Thermal Curve for Rhodochrosite. The thermal reaction in rhodochrosite which is responsible for the endothermic peak is the breakdown of the crystal structure, which involves the absorption of heat energy. Carbon dioxide is evolved and a low valence manganese oxide is formed. This is subsequently oxidized to a higher valence manganese oxide (hausmannite) and the heat liberated in the process is responsible for the exothermic peak (Beck, 1946). The areas under the peaks are a measure of the energy transformations involved.

The type thermal curve for rhodochrosite may be derived by the analysis of the mineral specimens already discussed. The purity of the specimen tested, as indicated by qualitative chemical analysis, x-ray powder patterns and optical study, and the size, shape and temperature of the endothermic and exothermic peaks of the differential thermal curve, are significant in determining the ideal rhodochrosite curve.

No specimen of pure rhodochrosite was sampled. Microscopic examination indicated that most of the specimens contained little impurity aside from other carbonates. All specimens except three showed some iron; in most, it was estimated to make up approximately 5–20% of the cations present. A number of samples showed iron as the only foreign cation. Of these, only two on the basis of the shape of the curve and the optical data appeared to be suitable as standards. Several others, especially Lake County #1 and #2 and Butte #2 showed smooth thermal curves with large amplitudes. These minerals, however, gave evidence of substitution in the lattice as shown by the upward shift of the endothermic peak and the semi-quantitative chemical analysis.

The Stassfurt and Oberneisen specimens, which appear of highest

purity and whose thermal curves probably approximate the ideal rhodochrosite curve, are shown in Fig. 7. Qualitative analysis of the material from these localities showed only a trace of iron in the Oberneisen specimen and traces of Fe^{++} and Mg^{++} in the Stassfurt specimen. Both curves are remarkable for smoothness and regularity. Their peaks occur in the lower part of the rhodochrosite range at 612°C. for the Stassfurt specimen, and 616°C. for the Oberneisen specimen. Since Fe^{++} in small but appreciable quantities does not affect the thermal curve peak to any noticeable extent, it may be assumed that these specimens give thermal curves that are close to pure MnCO_3 .

In summary, it appears that an ideal rhodochrosite thermal curve shows a sharp endothermic peak at about 615°C. , followed immediately by a somewhat less sharp exothermic peak in the range of 690°C. to 735°C. and a generally smooth, regular form. The exothermic peak temperature depends largely upon the geometry of the thermocouple. The high temperature side of the endothermic peak is much steeper than the low temperature side, which is characteristic of carbonates in general. In contrast, the low temperature side of the exothermic peak is steeper than the high temperature side. Finally, the temperature at which the curve breaks for the endothermic peak is fairly constant for specimens of high purity and uniform grain size.

D. Manganocalcite. A group of manganocalcite specimens from Franklin, New Jersey, was examined for fluorescence, manganese content, color after heating to 1020°C. , and thermal peak temperature. The results, summarized in Table 2, show a continuous downward shift in thermal peak temperature with increasing Mn content as qualitatively determined by controlled borax and soda bead tests and color of the powder after heating. Specimen #5 in the table indicated the highest percentage of Mn^{++} . An x -ray diffraction pattern of this specimen showed an appreciable shift of the lines toward rhodochrosite. (See Table 1.)

Conditions were maintained approximately constant in determining the fluorescence intensity, the concentration of Mn^{++} by bead tests and the thermal curves. A quartz-mercury lamp with a filter to eliminate the visible part of the spectrum from the source light was used.

W. L. Brown (1934) studied the fluorescence of manganocalcite as a function of manganese content. He showed that weak fluorescence was observable at 0.1% manganese, the maximum was reached at about 3.5%, was weak again at 10% and absent at 17%. This is consistent with the data in Table 2. An assumption of 10% manganese in specimen #5 on the basis of the shift in the x -ray diffraction lines is quite reasonable both in terms of the thermal curve shift, the fluorescence intensity, and the qualitative analysis.

That the fluorescence phenomena should go through a maximum while

TABLE 2. MANGANOCALCITE SPECIMENS, FRANKLIN, N. J.

No.	Description	Fluo- rescence	Qual. Chem. Analysis Bead Tests	Color after heating to 1020° C.	Thermal peak temper- ature
Iceland spar	clear transparent	none	no Mn	white	990° C.
#2	with zincite	very weak	no Mn	cream	980° C.
#3	coarsely crystalline with garnet	weak	trace	light brown	970° C.
#1	minor franklinite and willemite	moderate	trace-weak	light brown	975° C.
#6	white without other minerals	moderate	weak	medium brown	975° C.
#4	coarsely crystalline spotted with willem- ite	strong	moderate	chocolate brown	960° C.
#5*	minor willemite	weak	strong	dark brown	935° C.
rhodo- chrosite	Lake Co., Colo.	none	—	black	615° C.

* This specimen, American Museum of Natural History No. 10964, is estimated to have 5-10% Mn in cation position.

the thermal peak and x -ray line shifts appear to be linear is readily explained by the mechanism of the fluorescence postulated by Brown.

"If only a few atoms of manganese occupy similar positions to the calcium atoms in the crystal structure, their influence would be very small on the crystal as a whole and the atomic spacing would be practically that of pure calcite. This would produce a state of unstable equilibrium in the manganese atom, as it would occupy a larger space than it would require when in equilibrium in its own rhodochrosite structure. . . . As the number of replacing manganese atoms increases, it would be expected that the fluorescent emission would rapidly increase. With a further increase of replacing manganese atoms, however, there is a gradual shrinkage of the crystal structure, allowing the manganese atom less and less freedom for the separation of the electrons."

Finally a condition of stability would be reached in which fluorescence would no longer occur. Experimentally this occurs when roughly 20% of the calcium positions have been taken by manganese atoms.

In the course of this investigation several other "manganocalcites" were run from Franklin, New Jersey, Nordmark, Sweden, and Elbingerde, in the Hartz. These specimens proved to have several com-

ponents including dolomite or ankerite. Peaks corresponding to manganocalcite with Mn^{++} occupying up to 25% of the cation positions were distinguishable. The manganocalcite peaks had the following values which were qualitatively consistent with the concentration of manganese detected by bead tests: Nordmark 915°C ., Franklin 880°C ., and Elbingerode (labelled "rhodochrosite") 780°C .

Therefore, it seems that the substitution of Ca^{++} for Mn^{++} is continuous from rhodochrosite to calcite and this substitution results in a continuous shift of the x -ray lines and in a single endothermic thermal curve peak. A double endothermic peak clearly indicates the presence of more than one carbonate mineral.

The " d " values for some of the strong lines in the x -ray diffraction patterns of the samples, selected on the basis of the thermal and chemical data, as representative of various positions in the calcite-rhodochrosite series, have been computed. Although the line positions throughout each pattern exhibit measurable deviations from the positions of corresponding lines in the other patterns of the series these variations become more conspicuous in the outer "high angle" range. In Table 1 the calculated " d " values for the outermost strong high angle line in each pattern is given. The figures indicate a correlation of the x -ray data with that obtained from the thermal and semi-quantitative chemical studies.

VI. CONCLUSIONS

A study has been made of the differential thermal curves yielded by specimens of rhodochrosite and manganocalcite. Variations in curves have been critically examined in the light of x -ray, chemical, and optical data. The effect on the thermal curves of rhodochrosite produced by cation substitution in the crystal lattice has been investigated. The curves obtained from artificially prepared two-component mixtures of rhodochrosite with other carbonates have been analyzed for effects produced on the thermal curve by carbonate impurities.

The following conclusions have been reached on the basis of the above data.

1. In the examination of rhodochrosite by differential thermal analysis optimum results will be obtained if the following precautions are observed:

- (1) The fragment size should be restricted (minus 80, plus 200 mesh proved satisfactory) to obtain consistent thermal curves; larger fragments tend to raise the endothermic reaction temperature while smaller fragments tend to lower it appreciably.
- (2) In order to obtain reproducible exothermic peaks, the cover on the sample holder should be raised somewhat to allow free circulation of air. Furthermore, the geometry of the thermocouple head must be constant from one run to the next.

2. For the sixteen specimens tested, a range in endothermic peak temperature of 609° C. to 724° C. was found. Only one specimen showed a peak temperature higher than 667° C., and the majority showed endothermic peaks in the lower part of the range (609° C. to 635° C.).

3. The temperature at which the endothermic peak appears depends on the amount of substitution of Ca, Mg, and Fe for Mn in the lattice, and to a smaller extent on the concentration of the mechanically admixed impurities present. Ca and Mg tend to raise the endothermic peak temperature because substitution of Ca or Mg for Mn strengthens the cation-carbonate bond, and consequently a greater amount of energy is required to destroy this bond. For analogous reasons, substitution of Fe for Mn tends to lower the endothermic peak temperature.

4. The thermal curves of the Oberneisen, and Stassfurt specimens most closely approach the theoretical curves for pure rhodochrosite. This theoretical curve has a sharp endothermic peak at about 620° C., followed immediately by a less sharp exothermic peak. The areas under the two peaks are of the same order of magnitude.

5. Two-component mixtures of rhodochrosite prepared in varying proportions with calcite, dolomite and siderite showed:

- (1) A combination of the curves typical for each component.
- (2) A decrease in endothermic peak temperature with increasing foreign constituent.
- (3) A greater decrease in endothermic peak temperature per unit change in percentage composition in the high percentage impurity range than in the low percentage impurity range.
- (4) A direct relationship between area under the peak and percentage composition of the constituent responsible for the peak.

Thus a specimen containing intimately intergrown calcite and rhodochrosite can readily be distinguished from a specimen of rhodochrosite which has appreciable calcium substituting for manganese. The former would show two endothermic peaks of decreased amplitude and peak temperature. The latter would show a single peak well above that for pure rhodochrosite.

The thermal results obtained from mixtures of rhodochrosite with other carbonates indicate that it is possible to determine the percentage composition of a mixture within about 10–15% by noting the size of the endothermic and exothermic peaks, and the temperatures at which they occur.

BIBLIOGRAPHY

- BATEMAN, ALAN M., (1942), *Economic Mineral Deposits*, John Wiley and Sons.
- BECK, C. W., (1946), An improved method of differential thermal analysis and its use in the study of the natural carbonates: Harvard University Ph.D. Thesis.
- BROWN, W. L., (1934), Fluorescence of manganiferous calcites: *University of Toronto Studies, Geological Series* No. 36, 45.

- CUTHBERT, F. L., AND ROWLAND, R. A., (1947), Differential thermal analysis of some carbonate minerals: *Am. Mineral.*, **32**, 111.
- FAUST, G. T., (1944), Differentiation of magnesite from dolomite in concentrates and tailings: *Econ. Geol.*, **39**, 192-151.
- GRIM, R. E., AND ROWLAND, R. A., (1942), Differential thermal analysis of clay minerals and other hydrous materials: *Am. Mineral.*, **27**, 746-761; 801-818.
- HENDRICKS, S. B., GOLDRICH, S. S., AND NELSON, R. A., (1946), On a portable differential thermal outfit: *Econ. Geol.*, **41**, 41.
- KERR, P. F., AND KULP, J. L., (1947), Differential thermal analyses of siderite: *Am. Mineral.*, **32**, 678.
- KERR, P. F., AND KULP, J. L., (1948), Multiple differential thermal analysis: *Am. Mineral.*, **33**, 387-419.
- KRIEGER, P., (1930), Notes on an x-ray diffraction study of the series calcite-rhodochrosite: *Am. Mineral.*, **15**, 23-33.
- KULP, J. L., AND KERR, P. F., (1947), Multiple thermal analyses: *Science*, **105**, no. 2729, 413.
- MISER, H. D., (1941), Manganese carbonate in the Batesville district, Arkansas: *U.S.G.S., Bull.* **921-A**, 1-94.
- SPEIL, BERKELHAMER, PASK AND DAVIES, (1945), Differential thermal analysis: *U. S. Bur. Mines, Tech. Pap.*, **664**.

WHAT IS A MINERAL?

ALEXANDER N. WINCHELL,
*Emeritus Professor of Mineralogy,
University of Wisconsin.*

During the nineteenth century minerals were considered to be natural inorganic substances of *definite chemical composition*. This was the view of practically all mineralogists¹ of all countries. During the last fifty years this view has been modified slightly so that now a mineral is said to have a composition which is expressed in a definite formula², but varieties are recognized which involve variations from that formula. In the opinion of the writer this view is a decided improvement over the older one, but is still not satisfactory. An attempt will be made in the following paragraphs to explain the reasons for this opinion.

A mineral should not be defined in terms of any simple formula because the formulas assigned to most minerals give the composition only *approximately* and two samples of the same mineral only very rarely have exactly the same composition. Even a single crystal of one mineral may vary considerably in composition (and properties) in crystals showing zonal growths. Indeed, two zones in a single crystal of one mineral such as plagioclase may differ in composition so much that one zone corresponds approximately with one formula while another zone in the same crystal corresponds approximately with a different formula.

It is well known that many minerals cannot be defined even approximately in terms of composition alone. Thus, at least three different minerals (adularia, sanidine, and microcline) have approximately the composition, KAlSi_3O_8 , and at least six (α - and β -quartz, α - and β -tridymite, and α - and β -cristobalite) have more or less exactly the composition SiO_2 .

According to common usage at the present time, many minerals, such as labradorite, chrysolite, hypersthene, clinocllore, actinolite, and aegyrinaugite are merely arbitrarily defined portions of some series or system of continuous variation in composition.

The name of a mineral should be the name of a natural unit and not the name of something which has arbitrary and artificial boundaries. It is quite true that these arbitrary and artificial boundaries are useful, and names defined by such limits are desirable at least in some cases; but such names should be recognized as the names of varieties and not as the names of mineral species.

¹ The only exception known to the writer is G. Tschermak who held that plagioclase illustrated continuous variation in composition from $\text{NaAlSi}_3\text{O}_8$ to $\text{CaAl}_2\text{Si}_2\text{O}_8$.

² See, for example, *Dana's System of Mineralogy*, 7th Ed. Vol. 1 (1944).

The writer would define a mineral species as a crystalline phase³ found in inorganic nature.

In certain rare cases the phase is not crystalline, as illustrated by (amorphous) opal and (liquid) mercury and water. Rogers⁴ has suggested that amorphous types should be called "mineraloids"; if this idea is adopted it still leaves the liquid types as minerals which are not crystalline. But such examples are so rare that they may reasonably be regarded as exceptions which do not make it necessary to change the definition.

It is well known that a crystalline phase may vary in composition; in some cases the amount of variation which is possible is only slight, but in other cases, continuous variation is possible in any amount from 0 to 100 per cent leading from one chemical formula to another different formula; more than one kind of variation is often possible, sometimes to the same unlimited extent. Such continuous variation does not change one phase into another phase. In the same way all these variations should be included as one mineral, no matter whether that means that the composition of the mineral can be expressed (at least approximately by one formula or that two or even many formulas are necessary to express it.

It is clear that, as thus defined, the term mineral includes all "organic" compounds, such as carbonates, oxalates, etc., which are found in inorganic nature (whether or not they are also found in living organisms).

This definition of a mineral is not yet widely accepted, although it seems to be gradually growing in favor. It may be worth while to review briefly some of the effects of its acceptance on mineralogical nomenclature. It is interesting to find that some minerals (as thus defined) have names accepted by all, while others have no names. The oldest example of such a name is plagioclase which was used in this sense (and not as the name of a group of minerals) by Tschermak more than fifty years ago. Another familiar example is olivine, though to many mineralogists that is still considered to be the name of a group of minerals rather than the name of one mineral species.

On the other hand orthoclase, as at present used, is one name for at least two minerals, namely, adularia, and sanidine.

The following list gives examples of minerals and some of their varieties according to this definition:

³ As suggested by M. N. Godlevsky, *Min. Abst.*, **7**, 208 (1939). For a definition of phase see, for example, A. Findlay's *Phase Rule*, 8th Ed. (1938), or F. H. Getman and F. Daniels' *Outlines of Physical Chemistry*, 7th Ed. p. 308 *et. seq.* (1941).

⁴ A. F. Rogers, *Am. Mineral.*, **21**, 194 (1936).

<i>Species</i>	<i>Subspecies</i>	<i>End-members (and some intermediate formulas)</i>
Electrum ⁵	{ Gold Silver	Au Ag
Cerargyrite	{ Chlorargyrite Bromargyrite	AgCl AgBr
Gray Copper ⁶	{ Tetrahedrite Tennantite	$\text{Cu}_{10}\text{Zn}_2\text{Sb}_4\text{S}_{13}$ $\text{Cu}_{10}\text{Zn}_2\text{As}_4\text{S}_{13}$
Ilmenite	{ Geikielite Crichtonite Pyrophanite	MgTiO_3 FeTiO_3 MnTiO_3
Spinel	{ Talcspinel Hercynite Chromite Picrochromite Gahnite	MgAl_2O_4 FeAl_2O_4 FeCr_2O_4 MgCr_2O_4 ZnAl_2O_4
Magnetite	{ Magnetite proper Magnesioferrite Jacobsite Franklinite	FeFe_2O_4 MgFe_2O_4 MnFe_2O_4 ZnFe_2O_4
Columbite	{ Columbite proper Mangancolumbite Tantalite Mangantalite	FeCb_2O_6 MnCb_2O_6 FeTa_2O_6 MnTa_2O_6
Brownspar ⁷	{ Magnesite Siderite Rhodochrosite Smithsonite Spherochalcite	MgCO_3 FeCO_3 MnCO_3 ZnCO_3 CoCO_3
Dolomite	{ Magnesiodolomite Ankerite Ferrodolomite Mangandolomite	$\text{CaMg}(\text{CO}_3)_2$ $\text{Ca}(\text{Mg, Fe})(\text{CO}_3)_2$ $\text{CaFe}(\text{CO}_3)_2$ $\text{CaMn}(\text{CO}_3)_2$
Wolframite	{ Ferberite Hübnerite	FeWO_4 MnWO_4

⁵ Name suggested by Horace Winchell; designated "noble metal" in A. N. Winchell, *Elements of Mineralogy*, 225 (1942).

⁶ A. N. Winchell, *Elements of Mineralogy* (1942).

⁷ A. N. Winchell, *Elements of Mineralogy* (1942). Brownspar is simply a translation of the German name "braunspath."

<i>Species</i>	<i>Subspecies</i>	<i>End-members (and some intermediate formulas)</i>
Chalcanthite	{ Copper chalcanthite	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
	{ Siderotil	$\text{FeSO}_4 \cdot 5\text{H}_2\text{O}$
	{ Cobalt chalcanthite	$\text{CoSO}_4 \cdot 5\text{H}_2\text{O}$
Melanterite	{ Iron Melanterite	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$
	{ Boothite	$\text{CuSO}_4 \cdot 7\text{H}_2\text{O}$
Amblygonite	{ Hebronite	LiAlFPO_4
	{ Montebrazite	LiAlOHPO_4
Apatite	{ Chlorapatite	$\text{Ca}_5\text{ClP}_3\text{O}_{12}$
	{ Hydroxylapatite	$\text{Ca}_5\text{OHPO}_3\text{O}_{12}$
	{ Fluorapatite	$\text{Ca}_5\text{FP}_3\text{O}_{12}$
	{ Svabite	$\text{Ca}_5\text{OHAs}_3\text{O}_{12}$
	{ Ellestadite	$\text{Ca}_{10}(\text{OH})_2\text{S}_3\text{Si}_3\text{O}_{24}$
Plagioclase	{ Albite	$\text{Ab}_{100}\text{An}_0$ to $\text{Ab}_{90}\text{An}_{10}$
	{ Oligoclase	$\text{Ab}_{90}\text{An}_{10}$ to $\text{Ab}_{70}\text{An}_{30}$
	{ Andesine	$\text{Ab}_{70}\text{An}_{30}$ to $\text{Ab}_{50}\text{An}_{50}$
	{ Labradorite	$\text{Ab}_{50}\text{An}_{50}$ to $\text{Ab}_{30}\text{An}_{70}$
	{ Bytownite	$\text{Ab}_{30}\text{An}_{70}$ to $\text{Ab}_{10}\text{An}_{90}$
	{ Anorthite	$\text{Ab}_{10}\text{An}_{90}$ to $\text{Ab}_0\text{An}_{100}$
Muscovite	{ Muscovite proper	$\text{KAl}_2(\text{OH})_2\text{Si}_3\text{AlO}_{10}$
	{ Ferrimuscovite	$\text{KAlFe}(\text{OH})_2\text{Si}_3\text{AlO}_{10}$
	{ Picropengite	$\text{K}_2\text{MgAl}_3(\text{OH})_4\text{Si}_7\text{AlO}_{20}$
	{ Ferropengite	$\text{K}_2\text{FeAl}_3(\text{OH})_4\text{Si}_7\text{AlO}_{20}$
Lepidolite	{ Polyolithionite	$\text{K}_2\text{Li}_4\text{Al}_2(\text{OH}, \text{F})_4\text{Si}_8\text{O}_{20}$
	{ Paucilithionite	$\text{K}_2\text{Li}_3\text{Al}_3(\text{OH}, \text{F})_4\text{Si}_6\text{Al}_2\text{O}_{20}$
	{ Protolithionite	$\text{K}_2\text{LiFe}_4\text{Al}(\text{OH}, \text{F})_4\text{Si}_6\text{Al}_2\text{O}_{20}$
Biotite	{ Phlogopite	$\text{K}_2\text{Mg}_6(\text{OH})_4\text{Si}_6\text{Al}_2\text{O}_{20}$
	{ Eastonite	$\text{K}_2\text{Mg}_5\text{Al}(\text{OH})_4\text{Si}_5\text{Al}_3\text{O}_{20}$
	{ Siderophyllite	$\text{K}_2\text{Fe}_5\text{Al}(\text{OH})_4\text{Si}_5\text{Al}_3\text{O}_{20}$
	{ Annite	$\text{K}_2\text{Fe}_6(\text{OH})_4\text{Si}_6\text{Al}_2\text{O}_{20}$
Chlorite ⁸	{ Antigorite ⁹	$\text{Mg}_6(\text{OH})_8\text{Si}_4\text{O}_{10}$
	{ Amesite ¹⁰	$\text{Mg}_4\text{Al}_2(\text{OH})_8\text{Si}_2\text{Al}_2\text{O}_{10}$
	{ Daphnite	$\text{Fe}_4\text{Al}_2(\text{OH})_8\text{Si}_2\text{Al}_2\text{O}_{10}$

⁸ Many intermediate varieties have been named, such as clinochlore, prochlorite, penninite, thuringite, etc.

⁹ "Ferroantigorite," $\text{Fe}_6(\text{OH})_8\text{Si}_4\text{O}_{10}$, is a purely hypothetical end-member, being unknown in nature, even as an approximation.

¹⁰ Amesite is a doubtful end-member of chlorite, having a structure resembling that of kaolinite according to J. W. Gruner: *Am. Mineral.*, **29**, 422 (1944).

<i>Species</i>	<i>Subspecies</i>	<i>End-members (and some intermediate formulas)</i>
Montmorillonite ¹¹	Leverrierite	$\text{Al}_4(\text{OH})_4\text{Si}_8\text{O}_{20} \cdot 8\text{H}_2\text{O}$
	Beidellite	$\text{Al}_4(\text{OH})_4\text{Si}_6\text{Al}_2\text{O}_{18}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$
	Name?	$\text{Mg}_3\text{Al}(\text{OH})\text{Si}_7\text{AlO}_{19}(\text{OH}) \cdot 11\text{H}_2\text{O}$
	Name?	$\text{Mg}_3\text{Al}(\text{OH})\text{Si}_6\text{Al}_2\text{O}_{18}(\text{OH})_2 \cdot 11\text{H}_2\text{O}$
	Chloropal ¹²	$\text{Fe}_4(\text{OH})_4\text{Si}_8\text{O}_{20} \cdot 8\text{H}_2\text{O}$
	Canbyite(?)	$\text{Fe}_4(\text{OH})_4\text{Si}_6\text{Fe}_2\text{O}_{18}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$
	Name?	$\text{Mg}_3\text{Fe}(\text{OH})\text{Si}_7\text{FeO}_{19}(\text{OH}) \cdot 11\text{H}_2\text{O}$
Enstenite	Name?	$\text{Mg}_3\text{Fe}(\text{OH})\text{Si}_6\text{Fe}_2\text{O}_{18}(\text{OH})_2 \cdot 11\text{H}_2\text{O}$
	Enstatite	MgSiO_3
	Hypersthene	$(\text{Mg}, \text{Fe})\text{SiO}_3$
Clinoenstenite	Ferrosilite	FeSiO_3
	Clinoenstatite	MgSiO_3
	Clinohypersthene	$(\text{Mg}, \text{Fe})\text{SiO}_3$
	Pigeonite	$(\text{Mg}, \text{Fe}, \text{Ca})\text{SiO}_3$
Polyaugite ¹³	Clinoferrosilite	FeSiO_3
	Diopside	$\text{CaMgSi}_2\text{O}_6$
	Augite	$\text{Ca}(\text{Mg}, \text{Fe})\text{Si}_2\text{O}_6$ with $(\text{Mg}, \text{Fe})_2\text{Si}_2\text{O}_6$ and Al_2O_3
	Hedenbergite	$\text{CaFeSi}_2\text{O}_6$
	Johannsenite	$\text{CaMnSi}_2\text{O}_6$
	Acmite	$\text{NaFeSi}_2\text{O}_6$
Hornblende ¹⁴	Jadeite	$\text{NaAlSi}_3\text{O}_8$
	Tremolite	$\text{Ca}_2\text{Mg}_5(\text{OH})_2\text{Si}_8\text{O}_{22}$
	Actinolite	$\text{Ca}_2(\text{Mg}, \text{Fe})_5(\text{OH})_2\text{Si}_8\text{O}_{22}$
	Ferrotremolite	$\text{Ca}_2\text{Fe}_5(\text{OH})_2\text{Si}_8\text{O}_{22}$
	Tschermakite	$\text{Ca}_2\text{Mg}_3\text{Al}_2(\text{OH})_2\text{Si}_6\text{Al}_2\text{O}_{22}$
	Ferrotschermakite	$\text{Ca}_2\text{Fe}_3\text{Al}_2(\text{OH})_2\text{Si}_6\text{Al}_2\text{O}_{22}$
	Edenite	$\text{NaCa}_2\text{Mg}_5(\text{OH})_2\text{Si}_7\text{AlO}_{22}$
	Ferroedenite	$\text{NaCa}_2\text{Fe}_5(\text{OH})_2\text{Si}_7\text{AlO}_{22}$
	Hastingsite	$\text{NaCa}_2\text{Mg}_4\text{Al}(\text{OH})_2\text{Si}_6\text{Al}_2\text{O}_{22}$
	Ferrohastingsite	$\text{NaCa}_2\text{Fe}_4\text{Al}(\text{OH})_2\text{Si}_6\text{Al}_2\text{O}_{22}$
	Ferritremolite	$\text{Ca}_2\text{Fe}_3\text{Fe}_2\text{O}_2\text{Si}_8\text{O}_{22}$
	Ferritschermakite	$\text{Ca}_2\text{Fe}(\text{Al}, \text{Fe})_4\text{O}_2\text{Si}_8\text{O}_{22}$

¹¹ A. N. Winchell: *Am. Mineral.*, **30**, 510 (1945).

¹² The last four formulas of montmorillonite are those of the probable end-members of nontronite.

¹³ Some name seems to be needed for this mineral; clinopyroxene is not suitable since it would include clinoenstenite and spodumene. Augite is much the commonest subspecies, and the mineral includes not only augite, but also leucaugite, ferroaugite, magaugite, titanaugite, and aegirinaugite, so polyaugite seems an appropriate name (all the other subspecies being closely related to augite).

¹⁴ Hornblende is so complicated that recognition of three groups of subspecies seems desirable—namely "common hornblende"=tremolite to ferrohastingsite, oxyhornblende=ferritremolite to ferrihastingsite and soda-hornblende=glaucophane to eckermanite.

<i>Species</i>	<i>Subspecies</i>	<i>End-members (and some intermediate formulas)</i>
	Ferriedenite	$\text{NaCa}_2\text{Fe}_3\text{Fe}_2\text{O}_2\text{Si}_7\text{AlO}_{22}$
	Ferrihastingsite	$\text{NaCa}_2\text{Fe}_2(\text{Al}, \text{Fe})_3\text{O}_2\text{Si}_6\text{Al}_2\text{O}_{22}$
	Glaucophane	$\left\{ \begin{array}{l} \text{Na}_2\text{Mg}_3\text{Al}_2(\text{OH})_2\text{Si}_8\text{O}_{22} \\ \text{Na}_2\text{CaMg}_3\text{Al}_2\text{O}_2\text{Si}_8\text{O}_{22} \\ \text{Na}_3\text{Mg}_3\text{Al}_2\text{OOHSi}_8\text{O}_{22} \end{array} \right.$
	Gastaldite	$\text{Na}_2\text{MgAl}_4\text{O}_2\text{Si}_8\text{O}_{22}$
	Riebeckite	$\text{Na}_2\text{Fe}_3'''\text{Fe}''(\text{OH})_2\text{Si}_8\text{O}_{22}$
	Arfvedsonite	$\text{Na}_3\text{Fe}_4'''\text{Fe}''(\text{OH})_2\text{Si}_8\text{O}_{22}$
	Eckermannite	$\text{Na}_3\text{Mg}_4(\text{Al}, \text{Fe}')(\text{OH}, \text{F})\text{Si}_8\text{O}_{22}$
Tourmaline	$\left\{ \begin{array}{l} \text{Dravite} \\ \text{Schorlite} \\ \text{Elbaite} \end{array} \right.$	$\left\{ \begin{array}{l} \text{H}_4\text{NaMg}_3\text{B}_3\text{Al}_6\text{Si}_6\text{O}_{31} \\ \text{H}_4\text{NaFe}_3\text{B}_3\text{Al}_6\text{Si}_6\text{O}_{31} \\ \text{H}_4\text{Na}(\text{Li}, \text{Al})_3\text{B}_3\text{Al}_6\text{Si}_6\text{O}_{31} \end{array} \right.$
Melilite	$\left\{ \begin{array}{l} \text{Akermanite} \\ \text{Gehlenite} \\ \text{Hardystonite} \end{array} \right.$	$\left\{ \begin{array}{l} \text{Ca}_2\text{MgSi}_2\text{O}_7 \\ \text{Ca}_2\text{AlSiAlO}_7 \\ \text{Ca}_2\text{ZnSi}_2\text{O}_7 \end{array} \right.$
Pyralspite	$\left\{ \begin{array}{l} \text{Pyrope} \\ \text{Almandite} \\ \text{Spessartite} \end{array} \right.$	$\left\{ \begin{array}{l} \text{Mg}_3\text{Al}_2\text{Si}_3\text{O}_{12} \\ \text{Fe}_3\text{Al}_2\text{Si}_3\text{O}_{12} \\ \text{Mn}_3\text{Al}_2\text{Si}_3\text{O}_{12} \end{array} \right.$
Ugrandite	$\left\{ \begin{array}{l} \text{Uvarovite} \\ \text{Grossularite} \\ \text{Andradite} \end{array} \right.$	$\left\{ \begin{array}{l} \text{Ca}_3\text{Cr}_2\text{Si}_3\text{O}_{12} \\ \text{Ca}_3\text{Al}_2\text{Si}_3\text{O}_{12} \\ \text{Ca}_3\text{Fe}_2\text{Si}_3\text{O}_{12} \end{array} \right.$
Olivine	$\left\{ \begin{array}{l} \text{Forsterite} \\ \text{Chrysolite} \\ \text{Fayalite} \\ \text{Tephroite} \end{array} \right.$	$\left\{ \begin{array}{l} \text{Mg}_2\text{SiO}_4 \\ \text{Fo}_{90}\text{Fa}_{10} \text{ to } \text{Fo}_{70}\text{Fa}_{30} \\ \text{Fe}_2\text{SiO}_4 \\ \text{Mn}_2\text{SiO}_4 \end{array} \right.$
Scapolite	$\left\{ \begin{array}{l} \text{Marialite} \\ \text{Meionite} \end{array} \right.$	$\left\{ \begin{array}{l} \text{Na}_4\text{ClSi}_9\text{Al}_3\text{O}_{24} \\ \text{Ca}_4\text{CO}_3\text{Si}_6\text{Al}_6\text{O}_{24} \end{array} \right.$
Epidote	$\left\{ \begin{array}{l} \text{Clinozoisite} \\ \text{Pistacite} \\ \text{Piedmontite} \end{array} \right.$	$\left\{ \begin{array}{l} \text{Ca}_2\text{Al}_3(\text{OH})\text{Si}_3\text{O}_{12} \\ \text{Ca}_2(\text{Al}, \text{Fe})_3(\text{OH})\text{Si}_3\text{O}_{12} \\ \text{Ca}_2(\text{Al}, \text{Mn}, \text{Fe})_3(\text{OH})\text{Si}_3\text{O}_{12} \end{array} \right.$

A DEFINITION OF EUCLIDEAN GEOMETRICAL SYMMETRY*

HENRI BADER,

*Bureau of Mineral Research, Rutgers University,
New Brunswick, New Jersey.*

ABSTRACT

A predominantly verbal definition of Euclidean geometrical symmetry is given in the form of a series of definitions, which are briefly discussed. Examples of non-operational statements corresponding to symmetry operations are formulated. Sufficiency of the definition is not proved.

An understanding of the concepts of geometrical symmetry is of value to most scientists and of prime importance to mineralogists and physicists. Yet the student seeking a definition of geometrical symmetry most likely faces disappointment, particularly if he consults textbooks of mineralogy. There he will find either no definition at all or verbal ones which are at best vague and insufficient, at worst misleading. College students usually have a fair knowledge of Euclidean geometry, so there is no reason why they should not be given an adequate definition in terms with which they are familiar.

The following definition of symmetry is given in the form of a series of definitions in an effort to satisfy the mandate of unequivocal statement.

(1) A configuration is any collection of points in an Euclidean medium. (Line, plane or space.)

(2) One-to-one correspondence between the points of two configurations C and C' exists when each point of C' corresponds to a single point of C and no two points of C' correspond to the same point of C . (C and C' then have the same number of points.)

(3) A PrP' -relation is any relation defining a one-to-one correspondence between each point P of a configuration and a point P' of the same configuration. (The configurations C and C' are identical.)

(4) A PrP' -relation is a symmetry-relation when the following three conditions are fulfilled:

(a) The distance between any two points P_1 and P_2 is equal to the distance between the corresponding points P'_1 and P'_2 .

(b) At least one point P is not identical with its corresponding point P' .

(c) Every point P is also a point P' .

(5) A configuration possesses the property of symmetry when it validates one or more symmetry relations.

The first of the three conditions that make a PrP' -relation a symmetry relation needs no comment. The second condition excludes all generally

* Published by permission of the Director, Bureau of Mineral Research, Rutgers University.

valid relations, i.e. relations which do not give any significant information. Thus the covering operation of rotation through 360° is not a symmetry operation, the plane containing all the points of a configuration is not a mirror plane, and the line containing all the points of a configuration is not an axis of rotational symmetry.

The third condition may be somewhat less easy to understand. It implies that every point can occur "at both ends" of a symmetry relation. Consider for instance the PrP' -relation " P' lies one inch to the right of P ." Being a member of the configuration, P' is of course also a point P so that there must be a third point one inch to the right of P' , and so forth. We end up with a row of equally spaced points, starting at P and extending to infinity in a direction to our right. In this case our PrP' -relation is not a symmetry relation although it satisfies the first and second conditions. It is, however, a symmetry relation (translation) if the row of points also extends to infinity on our left. Now this extension is called for by the third condition, for if P is also a point P' , then it lies one inch to the right of another point of the configuration, which of course is located to the left of P , and so on.

We can now easily formulate the symmetry relations corresponding to the simple operations of translation, rotation, reflection, and inversion.

(1) The vector $P \rightarrow P'$ is parallel and equal to a given vector (direction and period of translation.)

(2) P and P' lie on a circle normal to and centered on a given line (axis of symmetry), and the angular rotation from P to P' has a given value (angle of rotation) and a given sense (clockwise or counter-clockwise).

(3) The line through P and P' is normal to a given plane (plane of symmetry) and the point of intersection with the plane bisects the line segment PP' .

(4) A given point (center of symmetry) bisects the line segment PP' .

Reflection and inversion are thus explicitly defined in non-operational terms, but the same is not true of translation and rotation. The bivectorial nature of translation is only implied by the above definition, as is also the irrelevance of the sense of rotation. Explicit definitions of translational and rotational symmetry follow.

(5) The line through P and P' is parallel to a given line (direction of translation) and the distance between P and P' has a given value (period of translation).

(6) P and P' lie on a circle normal to and centered on a given line (axis of symmetry), and the angular distance between P and P' has a given value (angle of rotation).

These satisfactory definitions can, however, not be given in the first

place because they reveal a one-to-two correspondence which is not explicit in the stated definition of symmetry, but which can be deduced from it.

Complex symmetry relations (corresponding to translatory-rotation, translatory-reflection, rotary-reflection, and rotary-inversion) can be defined as follows:

First simple relation: P' corresponds to P .

Second simple relation: P'' corresponds to P' .

Complex relation: P'' corresponds to P .

The point P' is not necessarily a member of the configuration.

Equivalence of points is also easy to define: Corresponding points are equivalent. Furthermore if P' corresponds to P by virtue of a symmetry relation and P'' corresponds to P' by virtue of the same or a different relation, then P and P'' are also equivalent.

An appraisal of the sufficiency of the definition of symmetry offered above indicates that it covers all the symmetries within the grasp of an Euclidean imagination, i. e. symmetries truly representable by means of points which have the single property of position. Symmetries only visualizable as properties of physical phenomena can be classed as not strictly Euclidean and are excluded by our definition. The holohedral spherical point group K_h , for instance, is covered by our definition while the enantiomorphous spherical group K is excluded. It also follows that geometrically C_∞ is indistinguishable from $C_{\infty v}$ and that $C_{\infty h}$ and D_∞ are equal to $D_{\infty h}$. Applied to continuous and semi-continuous symmetry groups, this criterion admits the second order groups as defined by Heesch¹, but excludes many of the symmetries described by Schubnikow².

In conclusion it is admitted that it remains to be proved that no asymmetric relation will satisfy the definition. A modification may become necessary to exclude asymmetric relations which have not occurred to the author.

¹ Heesch, H., Ueber die Symmetrien zweiter Art in Kontinuen und Semidiskontinuen: *Zeit. Krist.*, **73** (1930).

² Schubnikow, A., Ueber die Symmetrie des Kontinuums: *Zeit. Krist.*, **72** (1929).

Ueber die Symmetrie des Semikontinuums: *Zeit. Krist.*, **73** (1930).

THE AGGIE CREEK METEORITE FROM SEWARD PENINSULA, ALASKA*

EDWARD P. HENDERSON,

U. S. National Museum, Washington, D.C.

This iron meteorite, reported to weigh about 95 pounds (43.18 kg.), was found on Aug. 11, 1942, during a gold dredging operation in Aggie Creek, Alaska, (Lat. $64^{\circ} 53' N.$, Long. $163^{\circ} 10' W.$) by Mr. F. K. Dent of the Council Dredging Co., Nome, Alaska.

The first information that the United States National Museum had of this meteorite came from Mr. Eskil Anderson of the University of Alaska, who after visiting the meteorite display came to the office to ask if we had any record of this discovery. Some time later the U. S. National Museum obtained a 968 gram sample of this iron as a gift from Mr. Stuart H. Perry, who had acquired the specimen from Mr. Dent.

The following information concerning the location and conditions under which this iron was discovered was supplied by Mr. Dent.

This meteorite was found while dredging Aggie Creek for gold and was very close to bedrock when the dredge bucket picked it up. Bedrock at this point was about 12 feet deep from the surface. Aggie Creek is on Seward Peninsula, Alaska, and is a tributary to Fish River which empties into Golovin Bay about 90 miles southeast of Nome. It will be easy to locate Fish River and by following up this river about 40 miles you will find the Niukluk River empties into Fish River on the left side going up, and about 15 miles on up Fish River you will find Aggie Creek which flows into Fish River on the right side going up. About 2 miles up Aggie Creek is where this was found, just below the mouth of Rock Creek which empties into Aggie Creek. . . .

The whole piece weighed 95 pounds, and as previously advised the balance of it is at the University of Alaska. I was standing in the winch room of the dredge when I heard something heavy hit the dump plate and immediately went to investigate. Finding this piece so heavy that it would not float out the flume under the water pressure, I shut the dredge down to investigate. When I first saw it and lifted it I thought it was gold as it was nearly the color of gold all over, as you will notice on the specimen but when using a file on it was soon disappointed. This was on August 11, 1942.

The specimen of Aggie Creek meteorite has a highly altered iron oxide crust over the outside but this oxide crust is not much thicker than the crust on the average iron meteorite. In fact this crust is surprisingly thin for an iron which has been buried for any length of time. Perhaps this is due to the fact that there has been little oxidation as during the greater part of the year the ground water is frozen. On the polished face (Fig. 1) narrow bands of oxide can be seen which follow the borders of the kamacite. Weathering has removed all traces of the original surface structure, due to flight of the meteorite through the atmosphere, but there still remain a few small depressions on the specimen.

* Published by permission of the Secretary of the Smithsonian Institution.

This iron is a normal, medium octahedrite without any unusual structures. The kamacite bands vary in width between from 1 to 2 mm. and some of them extend 4.5 cm. in length. Some schreibersite is present and occurs in narrow elongated inclusions located about equidistant from the borders of the kamacite bands. In many places the schreibersite forms a series of isolated inclusions so located as to be almost always in the center of a kamacite band. It is estimated that there is about 1 per cent of schreibersite present in this meteorite. Only one small round



FIG. 1. Etch Pattern of the Aggie Creek, Alaska Meteorite $\frac{3}{4}$ Natural Size.

inclusion of troilite was seen; this is about 2.5 mm. in diameter and in it there is some schreibersite located between the troilite and the kamacite.

A slice was cut from this meteorite and after polishing and etching, an area, with typical average structure for this iron, was selected for the chemical analysis. This was treated as follows. The selected sample for analysis was divided into two portions and a specific gravity determination was made on each portion. The two pieces were then dissolved in 1-3 hydrochloric acid and the gas liberated was passed through a series of wash bottles containing lead acetate solution to collect any hydrogen sulfide gas that would be given off from the troilite. After 36 hours of this acid treatment, and many intermittent boilings, the acid soluble portion was decanted and separately analyzed. The weights of the re-

TABLE 1. ANALYSIS OF AGGIE CREEK, ALASKA METEORITE
E. P. HENDERSON, *analyst*

	A	B	C	
Fe	8.3590 gms.	.0717 gms.	8.4307 gms.	90.89%
Ni	.7595 "	.0332 "	.7927 "	8.54
Co	.0589 "	.0033 "	.0622 "	.67
P		.0175 "	.0175 "	.18
S	none	none	none	.00
Insol.		.0030 "	.0030 "	.03
	9.1774 gms.	.1287 gms.	9.3061 gms.	100.31%
Sp. G.	8.004			
	7.96			
			Mol. Ratio $\frac{\text{Fe}}{\text{Ni, Co}} = 10.42.$	

covered elements are given in Table 1 (A). The insoluble residue from the 1-3 hydrochloric acid was than dissolved in aqua regia and analyzed separately, (B). The results of B indicate that the insoluble residue is schreibersite, but because the quantity of material available for this

TABLE 2. METEORITES WITH COMPOSITIONS SIMILAR
TO THE AGGIE CREEK IRON

	Aggie Creek, Seward Penin- sula, Alaska	Drum Mts., Utah	Mbosi, Tan- ganyika, E. Africa	Baque- dano, Atacama Desert, Chile	Karee Kloof, Cape Province, S. Africa	Lanton, Missouri	Moorum- bunna, Central Australia
		1	2	3	4	5	6
Fe	90.89	90.70	90.45	90.90	90.79	90.40	89.53
Ni	8.54	8.59	8.69	8.82	8.27	8.33	8.82
Co	.67	.58	.66	.15	.68	.61	.56
P	.18	.tr	.11	.24	.24	.18	.29
S	.00	.00	.01	.05	—	—	.02
Cu	N.D.	N.D.	tr.	.03	.03	—	.07
Insol.	.03	.01	.03	.01	.03	.005	.30
Mol. Ratio Fe/Ni+Co	10.42	10.47	10.23	10.68	10.76	10.64	10.08

1. *Smithsonian Misc. Coll.*, **110**, No. 12 (1948), E. P. Henderson and S. H. Perry.
2. *Mineral. Mag.*, **22**, 487 (1931). D. R. Grantham and Frank Oates.
3. *Am. Mineral.*, **17**, 357 (1932). Charles Palache and F. A. Gonyer.
4. *Mineral. Mag.*, **20**, 134 (1923). G. T. Prior.
5. *Jour. Geol.*, **42**, 305 (1934). James S. Cullison and Garrett A. Muilenburg.
6. *Tran. Royal Soc. S. Australia*, **70** (2) (1946). A. B. Edwards and D. Mawson.

analysis was so small, the results are not much more than of qualitative importance and must not be considered as an analysis of schreibersite.

The sum of the determinations in *A* is 9.177 gms. and the weight of the sample originally taken was 9.275 gms. Thus the sum of *B* should be 0.098 gms., whereas 0.1287 gms. were found. With *A* there was ample solution to make check determinations, but not with *B*, so the analytical errors are essentially confined to the results shown in *B*. It can be found by simple calculation that the schreibersite content of Aggie Creek meteorite is somewhere between 1 and 1.3 per cent by weight. The analysis of this meteorite is the sum of *A* and *B*, and reported in column *C*.

The analysis of Aggie Creek meteorite is remarkably similar to several other iron meteorites from widely separated localities, Table 2. It may be that a detailed metallographic study would show that there are certain differences in these indicating that they have had different histories, but until these are so studied it would appear that these make a rather definite group of octahedral irons which may be cosmically related.

It can not be established how long ago or how closely spaced in time these falls occurred as none of these are witnessed falls. These may have come from a swarm of meteors of similar origin and came to our earth within a brief interval of time. This is mere conjecture and is offered only to stimulate suggestions regarding this possibility.

SUPPLEMENTARY NOTE ON THE AGGIE CREEK METEORITE

CHARLES P. OLIVIER,

Flower Observatory, Upper Darby, Pa.

While in Washington for the meeting of the A.A.A.S. I had an opportunity to see the manuscript on this meteorite and my attention was called to the fact that this iron had almost identical composition with several other meteorites listed for comparison. This led to some discussion on the subject which may be of interest to the readers of the article.

The fundamental question is whether meteorites of similar composition found even in different hemispheres could ever have been part of a single body which disrupted for some reason or other, which for this purpose need not necessarily be explained. An answer to this question, in our present state of knowledge, can I believe, be given partly from analogy, using the example of meteor streams.

Ignoring the question of the origin of such a stream as the August Perseids, we do know that for several days, as admitted by everyone, or for some weeks if we take the opinions of others, the earth meets

meteors which evidently belong to the same system. The common origin of all meteors of a given stream is generally admitted, yet, accepting the shortest estimate of a week's duration of activity, the earth meets meteors from the same stream over a distance of two per cent of the earth's orbit, roughly 12 million miles. During this interval of time, a week or more, meteors moving in approximately parallel paths meet the earth, are seen at every hour and every place, except those too far south for the radiant to rise. But at a given place and for a period of a few hours, the radiant is not a point but an area of 1° to 2° in diameter. This means that meteors, having a common origin, due to the perturbations are gradually shifted from their original orbits, yet not so much but that their family connections can be traced. Many other meteor streams act similarly.

Supposing that in disruption of a large body vast numbers of fragments of all sizes are formed, a certain proportion will follow almost but not absolutely the orbit of the parent body, the deviations being due both to succeeding perturbations from the planets and also to slight original differences of velocity of projection at the disruption. Evidently the orbits of most of the innumerable fragments would never meet the earth, their orbit planes having every inclination in space. That more than one fragment would be so well aimed as to strike the earth would mean that such fragments came from a very small portion indeed of the disrupted body, hence often may be of similar composition. If there is the minutest difference in projection velocities these bodies would follow one another at distances which would increase with time and not be in precisely the same orbits. An example of such a case is the periods calculated for the disrupted nucleus of the Great Comet of 1882, the results of which may be found in *Comets*, pp. 40-44, C. P. Oliviers.

If the above reasoning is correct, meteorites from the same very small portion of any disrupted body could fall on the earth, striking any place. We would not have the least reason to think the places of fall should be near one another. Further, they need not strike at one time, but could fall at the same approximate date over a long period of years. To carry this period into thousands of years would not be justified from the probabilities involved, but it might be over a considerable period.

In conclusion, any point of the earth could receive such fragments, provided only that the radiant point of the stream rose above the horizon. The meteorites need not fall simultaneously nor along the great circle. It seems, therefore, a perfectly possible hypothesis that the seven meteorites mentioned, are possibly of identical primordial origin with Aggie Creek. It could indeed be disproved only by showing that the orbits could not have been similar, and such proof seems totally unattainable since none of these falls was witnessed.

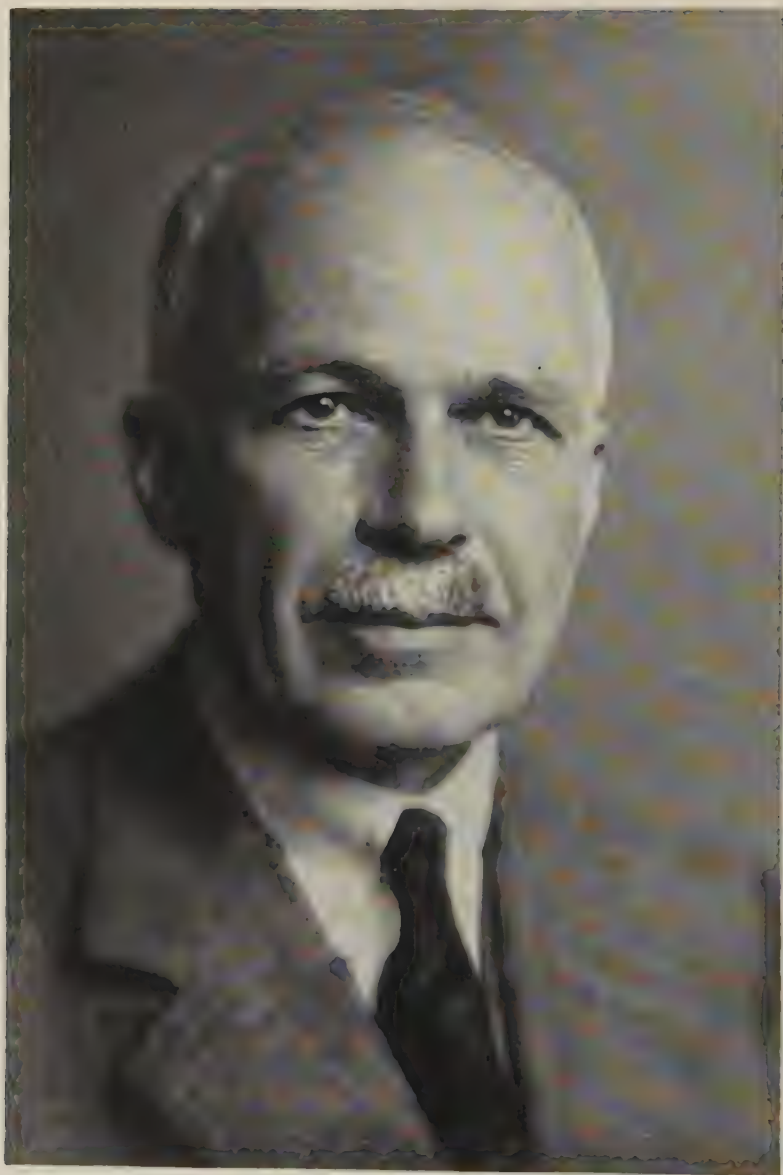


Photo by Walter Stoneman of J. Russell and Sons, London

WILLIAM LAWRENCE BRAGG

RECIPIENT OF THE ROEBLING MEDAL OF THE
MINERALOGICAL SOCIETY OF AMERICA

PRESENTATION OF THE ROEBLING MEDAL OF THE
MINERALOGICAL SOCIETY OF AMERICA TO
WILLIAM LAWRENCE BRAGG

INTRODUCTION

GEORGE TUNELL,

University of California, Los Angeles, California.

In 1936 the Council of the Mineralogical Society of America directed that a medal be designed in honor of Colonel Washington Augustus Roebling. Colonel Roebling's interest in mineralogy began while he was a student at Rensselaer Polytechnic Institute. He became closely associated with the Mineralogical Society of America immediately after its organization, and in 1924 served as its Vice-President. His support of the Society and its Journal and his bequest of his comprehensive collection to the United States National Museum will long be remembered by mineralogists. The award of the Roebling Medal was to be made for notable contributions to mineralogy in America and abroad.

The idea that crystals are built up of units put together in a regular way has been in the minds of mineralogists since the time of Hooke and Guglielmini. The mathematical theory of regular three dimensional structures built up of identical units was carried to completion in the latter part of the nineteenth century largely independently by Fedorov, Schoenflies and Barlow. However, no physical method then existed by which the arrangement of the constituent particles in any crystal could be determined. In 1912 the diffraction of x -rays by crystals was discovered by von Laue with the experimental aid of two assistants, Friedrich and Knipping. At that time Sir William Bragg had been studying the ionization effects of x -rays and had concluded that x -rays are corpuscular in nature. His son, W. L. Bragg, now Sir Lawrence Bragg, attempted to find an explanation for von Laue's results in terms of corpuscular x -rays, but soon concluded that the wave explanation of von Laue was correct. However, Sir Lawrence also realized that some features of von Laue's explanation could not be correct. The shapes of the spots and their behavior when the crystal was tilted suggested to Sir Lawrence that x -rays, not just of certain specific wave-lengths as von Laue had supposed, but of a range of wave lengths—analogueous to white light in the visible region—were reflected from crystal planes. From this work the fundamental equation of x -ray diffraction has become known as Bragg's law. Soon afterward he made x -ray photographs of potassium chloride and sodium chloride and deduced their complete atomic arrangements; these were the first crystal structures analyzed, and, as is well known, this achievement

has led to the development of a new branch of science which deals with the atomic arrangements in matter.

The invention of the ionization spectrometer by W. H. Bragg marked another important advance, and by its application the structure of the diamond was elucidated by W. H. and W. L. Bragg. With the aid of this new instrument W. L. Bragg in 1913 solved the structures of sphalerite pyrite, fluorite and calcite.

After these simple structures had been analyzed it became possible to attack successfully those of lower symmetry. Thus, in 1924, W. L. Bragg deduced the arrangement in the orthorhombic mineral aragonite. The silicate minerals make up most of the earth's crust; they often occur in good sized crystals suitable for investigation by the ionization spectrometer and partly for this reason they became a special object of study by Sir Lawrence and his collaborators. Their analyses of diopside, olivine, chrysotile, beryl, phenacite, willemite and others of this class revealed the basic features of the constitution of the silicates and revolutionized our conceptions of the chemical bonds that cement their crystal edifices together. In the investigations of these complicated structures use was made of the representation of the distribution of electron density in the crystals by Fourier series; this numerical and graphical method, first suggested by W. H. Bragg, has been perfected by W. L. Bragg and subsequent workers, and today is widely applied in investigations of atomic arrangements.

One of the chief reasons why we are much concerned with the fine structure of matter is that it gives us the key to so many physical and chemical properties. The nature of the dependence of the optical properties on the atomic arrangements in crystals was shown by W. L. Bragg's calculations of the refractive indices of aragonite and calcite from their structures in 1924. The properties of some metallic alloys, as well as of some sulfide and silicate minerals, depend not only on their structures, but also on the degree of ordering into superstructures. Much insight has been gained into the nature of order-disorder transformations by the work of Sir Lawrence and his school. The importance of these phenomena in rock minerals was emphasized by Past President M. J. Buerger in his address before the Society a year ago.

In recognition of these and other contributions the Council of the Mineralogical Society of America has resolved that the Washington Augustus Roebling Gold Medal be awarded to Sir Lawrence Bragg.

Professor Bragg was born in Adelaide, S. Australia. He attended St. Peters College in Adelaide and Adelaide University. Subsequently he studied in Trinity College, Cambridge, where in 1914 he became Fellow and Lecturer in Natural Sciences. In the same year he received the Bar-

nard Medal. In 1915 he was awarded the Nobel Prize for Physics jointly with his father on their investigations of x -rays and crystal structures. In 1931 he received the Hughes Medal of the Royal Society and in 1946 the Royal Medal of the Royal Society. From 1919 to 1937 he was Langworthy Professor of Physics in Victoria University of Manchester; in 1937 and 1938 he served as Director of the National Physical Laboratory; since 1938 he has been Cavendish Professor of Experimental Physics in Cambridge. He is a fellow of the Royal Society, Honorary Member of the Institute of Metals, Corresponding Member of the Academy of Sciences of Paris, Honorary Member of the Swedish Academy of Sciences, Member of the American Philosophical Society, Honorary Member of the New York Mineralogical Club, Member of the Chinese Physical Society, Foreign Associate of the National Academy of Sciences of Washington, Associate of the Royal Academy of Sciences of Belgium, Honorary Fellow of the Royal Society of Edinburgh, Honorary Member of the Royal Irish Academy, President of the International Union of Crystallography, and President of the British Association for the Advancement of Science. He is an Officer of the British Empire. During the first World War he served as Technical Adviser on Sound Ranging to the Map Section of the General Headquarters in France, and was awarded the Military Cross. During the second World War he acted as Coordinator of British, Canadian and American Military Research.

Most of the results of the researches of Sir Lawrence have appeared as scientific papers of which there has been a long series. He has also written a number of books, of which "*X-Rays and Crystal Structure*" and "*Atomic Structure of Minerals*" have been of particular value to mineralogists. Students, not only British but also of other nationalities, have gone to his laboratory to learn the methods of x -ray analysis, and from him they have received illuminating instruction and kind counsel. Through them, as well as directly, the stimulating influence of Sir Lawrence is felt in America and other countries.

Mr. President, it is my valued privilege to introduce Professor Sir Lawrence Bragg.

PRESENTATION

President M. A. Peacock handed the medal to Sir Lawrence Bragg with the words:

WILLIAM LAWRENCE BRAGG, in recognition of the fundamental and illuminating work you have done on the ultimate structure of crystals and the impetus and direction that this work has given to the study of minerals, I have the honour to present you with the Roebbling Medal of the Mineralogical Society of America.

ACCEPTANCE OF THE ROEBLING MEDAL OF THE
MINERALOGICAL SOCIETY OF AMERICA

W. L. BRAGG,

Cavendish Laboratory, Cambridge, England.

An occasion such as this must always be a very pleasant one to the proud recipient of the award, and I think it is doubly so when, as in the present case, the award comes from colleagues in a branch of science other than one's own. You have gone outside your own body today in awarding me the Roebling Medal, for no one, however kind and generous, could describe me as being a mineralogist. I am glad that you do not expect the recipient of the medal to pass a simple examination in mineralogy before he can accept his prize, for I am sure I would fail in that test. It is not merely a matter of knowing the subject, it is a deeper and more fundamental difference in outlook which divides the physicist from the mineralogist. Professor Niggli put this point very clearly in his address to you when he received the medal last year. An exact scientist endeavours to simplify and generalize problems so that comparatively unequivocal decisions can be made. Followers of descriptive sciences such as mineralogy and petrology can never approach their problem from a one-sided standpoint, but must consider how products of nature came to be, "what ultimate causes (irrespective of chemistry and physics) gave them their peculiar aspect and relationship to other occurrences." I have been deeply interested in the structure of minerals but have always viewed them with a physicist's idealization and simplification. I remember that I once incurred the disapproval of Spencer, my compatriot who received the medal in 1940. I had described the atomic arrangement of a beryl crystal, but had omitted any reference in my paper to the composition of the particular crystal I had studied or the locality from which it came. Spencer as a mineralogist naturally thought that this greatly lessened the value of the analysis, but of course as a physicist I was only interested in the perfect arrangement of a crystal of ideal composition, the scheme of structure common to all beryl crystals, and it never occurred to me to ascertain what particular variety of beryl some kind friend had given me to analyze. Again, I remember an occasion when I gave a lecture at the Sorbonne in Paris on the structure of silicates. My chairman was Professor Mauguin, holder of the chair of mineralogy, and he was deeply shocked to hear me begin my lecture with the statement that there were only six minerals in the earth's crust if one neglected tiresome details. When the lecture was over, he led me firmly to a great collection near the theatre where endless specimens

were displayed in their cases, and sweeping his arm dramatically said to me 'Les six minéraux!'

I feel it all the more an honor that you should have seen fit to make this award to one who can make no pretense of knowledge of the descriptive side of your fascinating subject. My contribution has been an attempt to increase our knowledge of the fundamental features of atomic arrangement in idealized mineral structures. The analysis of crystalline arrangement by x -rays is a borderline subject, and to me one of its greatest rewards has been the contacts I have made with colleagues in other branches of science—chemistry, metallurgy, biochemistry, and mineralogy. A prophet is said to be not without honor save in his own country and amongst his own kith and kin. Indeed we see today an instance of a prophet receiving a much prized honor in a country not his own and from scientists who are not kindred physicists.

An occasion like this is an excuse for personal history. I am particularly pleased at getting the medal because all the crystals which were analyzed in the beginning of x -ray analysis were minerals—rock salt, zincblende fluor, pyrites, diamond, calcite and others. This was partly due to our needing large and perfect specimens for the x -ray spectrometer which my father designed, the instrument with which all the data for analyzing these crystals were obtained.

But I think an even more important reason was that the only people who had kept alive the study of crystals were the mineralogists. It is perhaps fair to say that the chemists knew that there was more than one kind of crystal—they knew of two kinds, needles and plates. But the rest of the scientific world with a few eccentric exceptions had never thought of the laws of formal crystallography and the possible ways of making a pattern in three dimensions. When Laue discovered x -ray diffraction, my father was intensely interested because he had speculated deeply on the nature of ionization by x -rays. I became interested through discussions with my father, but I think the decisive factor, as far as I was concerned, which led me to interpret Laue's photographs in terms of the crystal structure of the zincblende crystal he used, was a paper on Pope and Barlow's theory of valency volumes. This paper was given to a society of young scientists, and it introduced me to the geometry of three-dimensional structures and to such ideas as close-packing of spheres. But here I have a terrible confession to make. I was so ignorant of anything to do with crystallography that when I tried to explain the genesis of Laue's picture by reflections of the x -rays from atomic planes I invented my own system for naming these planes. I was blissfully unconscious that crystallographers had already given some thought to this point of detail!

I was soon put right by Hutchinson, at that time lecturer in the mineralogy department at Cambridge, and later its professor. In my young days the professor was Lewis and he had given strict orders that no mineral should ever leave the safe-keeping of the collection at Cambridge. I shall never forget Hutchinson's kindness in organizing a black market in minerals to help a callow young student. I got all my first specimens and all my first advice from him, and I am afraid that Professor Lewis never discovered the source of my supply.

After the 1914-18 war we developed more powerful forms of *x*-ray analysis in my research school at Manchester, and cast round for subjects on which to try our new methods. I chose the silicates because fine crystals of them were available and because they were a good deal more complex than anything we had yet attempted. The work had a quite unexpected reward; the natural order of the silicates suddenly became clear in all its beauty and simplicity. I always regard this as one of the most exciting and aesthetically satisfying researches with which I have been associated. The significance of the formulae of silicates, the rather bewildering way in which atoms could be replaced by others, and the relation between the different families, was seen to be part of a simple geometrical scheme of linking silicon-oxygen tetrahedra together. One interesting feature of this new work was the complete justification of the mineralogist in basing his classification on crystalline form and not on chemical constitution.

Many contributed to the final elucidation of silicate structure. I always think the turning point was marked by the successful analysis of the pyroxene diopside. I brought over to the U. S. A. the measurements which West and I had made in Manchester, when I came to Cambridge as a visiting professor in the Massachusetts Institute of Technology in 1928. I was fortunate to find a clever research student willing to apply himself to the problem and he found the solution. I feel proud that I enticed Professor B. E. Warren to take up *x*-ray analysis, for you will be familiar with the fine work on crystals and glasses which he has done. At Manchester I had an active collaborator in Zachariasen, now professor in Chicago, who had the reputation in the laboratory of turning out a crystal structure a day when most people took months to complete an analysis. The silicate structures afford one of the finest examples of 'Pauling's Rules' for the coordination of ionic compounds. Then again one of my staff at Manchester, W. H. Taylor, solved the important feldspar structures. He is still with me at Cambridge and I am glad to say that he has turned his attention again to feldspar structures. His original work showed that the same general scheme ran through them all, whether monoclinic or triclinic, as indeed the mineralogist had always

divined. He has done some beautiful work on the mixed potassium-sodium feldspars, and is now tackling such problems as microcline, sanidine, and the bewildering complexities of the plagioclase series. Finally, we cannot exaggerate the debt we all owe to V. M. Goldschmidt whose brilliant work on geochemistry has opened up a new branch of science. In receiving your award for the contributions which x-ray analysis has made to our knowledge of minerals, I feel strongly how short a way I would have gone had I not been in the company of these pioneers.

To refer again to the address which Professor Niggli gave when he received the medal last year, he told us that as a young man he had been strongly advised by his friends to apply his obvious scientific ability to one of the more fundamental sciences. They told him that the study of the lithosphere was already so advanced as to leave only routine work still to be done, and Niggli declared that he had not regretted his refusal to accept this advice. I had a similar experience. Soon after we all returned to our laboratories in 1919 scientific friends advised me to drop the study of crystals. They pointed out that all crystals would soon be worked out, and that I would find myself out of a job. I did not take their advice and I also have no regrets. I remained faithful to my first love, the study of the atomic architecture of matter, and I feel that it has provided me with an absorbingly interesting scientific life, bringing me into contact with other scientists in many other subjects. If it were necessary, I should be still further fortified in my belief that I chose well by your generous award of the Roebling Medal today, a compliment I deeply appreciate and for which I tender my warmest thanks.

MEMORIAL OF ALFRED LACROIX

J. ORCEL, *Museum National d'Histoire Naturelle, Paris*.*

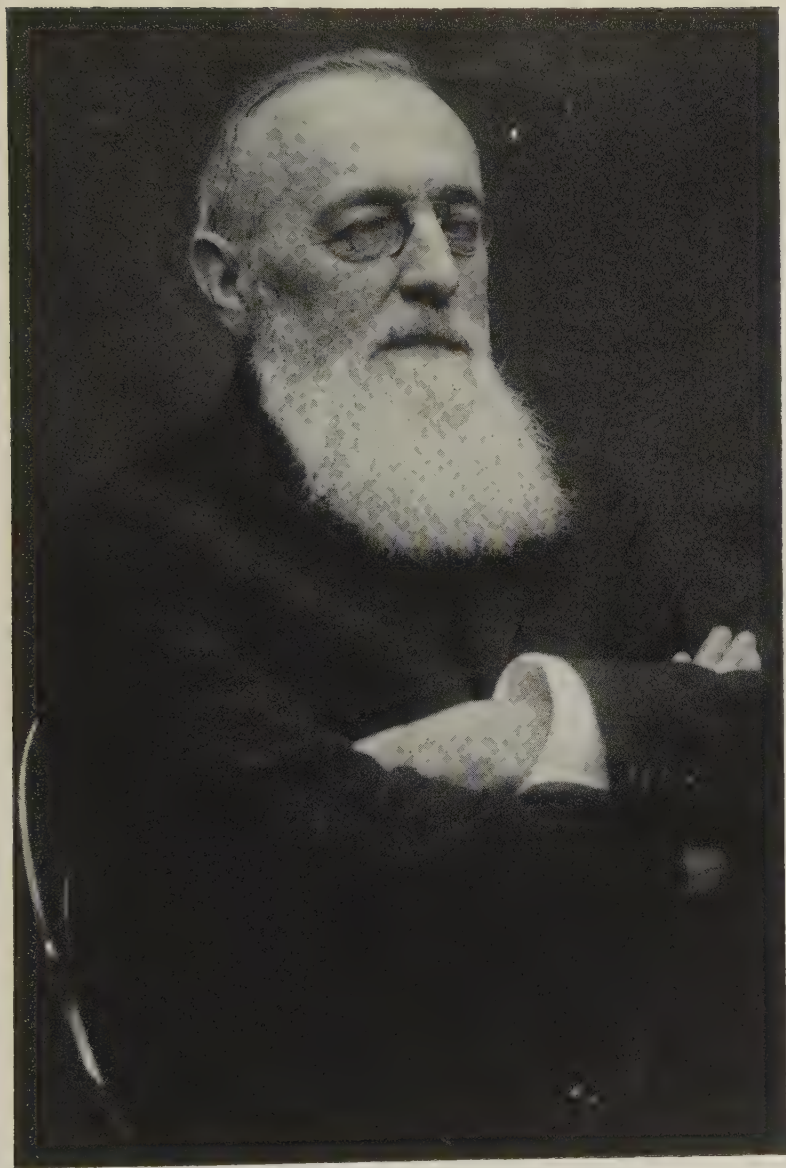
On March 16, 1948, the Mineralogical Society of America lost one of its most eminent foreign correspondents, A. Lacroix, a man of worldwide reputation.

François Antoine Alfred Lacroix was born at Mâcon, France, on February 4, 1863. His grandfather, Tony Lacroix, who had been Vauquelin's technician at the Museum of Natural History in Paris and whose hobby was mineralogy, must have had an influence on his vocation. After studying pharmacy, A. Lacroix very soon turned to geology and mineralogy. He worked under A. Des Cloizeaux and F. Fouqué, whose son-in-law he was later to become. In 1887 he was an assistant at the "Collège de France" and also worked at the "Service de la Carte Géologique de France"—the French Geological Survey. In 1889 he obtained his doctorate with a dissertation on pyroxene gneisses and wernerite rocks. In 1893, as Professor of Mineralogy at the Museum, he succeeded his master Des Cloizeaux, whose chair he occupied with distinction until his retirement in 1937. He completely reorganized the mineralogical exhibits in the Museum, increasing both their attractiveness and their pedagogical value, and he turned the Mineralogical Laboratory of the Museum into a widely renowned research center. Elected to the "Académie des Sciences de l'Institut de France" in 1904, he became its Perpetual Secretary on June 8, 1914. He dedicated himself to the high duties of this office, fulfilling them until his death with great competence, and integrity.

A. Lacroix's work is monumental and quite varied, dealing with mineralogy, geology, petrology, vulcanology, and even the history of sciences. On the occasion of a historical sketch he was writing about the "third seat" of the Mineralogy Section of the Academy of Sciences, in a few striking words he discreetly pointed out the nature of his work. "On January 11, 1904," said he, "the Academy returned to the study of minerals. It elected a mineralogist who was studying physical and chemical properties of mineral matter, no longer as an end in themselves, but as means of characterization for natural history purposes; who, in the field and in the laboratory, was finding his life work in a union of mineralogy, geology and the physics of the earth; a naturalist lured by research in far away colonies, roaming all over the world in the pursuit of volcanoes, their eruptions and their products. You will not be surprised," he then added, "if I leave a gap in this account."

From Lacroix's work considered as a whole, we sense a remarkable

* Translated from the French by Professor J. D. H. Donnay.



ALFRED LACROIX
1863-1948

continuity of ideas, based on a widened interpretation of the concept of mineral species, which he redefined and enriched. His "Minéralogie de la France et de ses Colonies," published from 1893 to 1913, and his "Minéralogie de Madagascar," which appeared in 1922 and 1923, were conceived on a completely new plan. By accumulating and correlating a considerable number of original observations pertaining to crystallography, optics, and lithology, he showed how necessary it is to maintain a proper balance between the various methods of observation, if one's purpose is not merely to give an accurate description of isolated minerals but rather to understand their mode of occurrence, associations, genesis, and transformations in nature. Thus he studied in detail the role which minerals play in the constitution of rocks, and removed the artificial boundaries that had so long separated mineralogy and petrography. By careful observations, made mainly in the Pyrénées, he renewed our knowledge of contact metamorphism, by proving the existence of endomorphic transformations suffered by granitic magmas in contact with limestone. His conclusions supported the theory that mineralizers and volatile emanations of eruptive magmas play a dominant role in metamorphism, a theory long advocated by French petrographers, especially by Auguste Michel-Lévy. His investigations on the *enclaves* of volcanic rocks have thrown light on the metamorphism produced by lavas. He showed that basic rocks differ from acid rocks in the effect they have on their *enclaves*; the former exert a purely thermal action, while the latter give rise to chemical alterations. In a masterly memoir (1907) on the silicated products of the 1906 eruption of Mount Vesuvius, he treated the transformations of lavas under the action of volatile magmatic emanations and introduced the now classical concept of autopneumatolysis. Not only did A. Lacroix study the materials ejected by volcanoes (Auvergne, Aetna, Vesuvius, Santorin, Iceland, Antilles, Japan, Java, Réunion, Comoro Archipelago, Madagascar, New Hebrides, volcanoes of the Pacific, Tibesti), he also spent a great deal of time scrutinizing the mechanism of volcanic eruptions. Thanks to his work on Mount Pelée, we now understand how domes and *nuées ardentes* are formed.

For a long time A. Lacroix had been interested in the classification of eruptive rocks, not with the limited aim of a systematician, but rather with the idea in mind of determining their mutual relationships and their conditions of formation, by including in their discussion both mineralogical observations and quantitative chemical data. From the classification proposed by the American petrographers Cross, Iddings, Pirsson, and Washington, he borrowed the idea of magmatic parameters and, by making a judicious use of it, he was able to account for the formation of several lithologic types the origin of which had remained unclear, for instance

those which he called the doliomorphous types, the heteromorphous types (mineralogically different rocks with identical chemical compositions), the pegmatitoid types, etc. Combining the knowledge gained from the syntheses performed by Fouqué and Michel-Lévy, by Bowen, and by a few others, with the results of his own numerous observations on artificially molten rocks (as in the case of the products of the fire of St. Pierre, Martinique), he was able to determine the conditions of stability for certain constituents of eruptive rocks.

A. Lacroix particularly studied the formation of pegmatites, especially the Madagascar pegmatites, which he compared with those found in U.S.A. He first made the distinction between potassium pegmatites and sodium-lithium pegmatites. He stressed the existence of two crystallization stages in the latter: first a constructive one, then a destructive one yielding new minerals at the expense of minerals formed during the first stage. In his classical work on laterite formation, he explained the mechanism of concentration of iron and aluminum hydroxides during the alteration of silicate rocks in tropical and subtropical climates. The study of terrestrial rocks led him to that of meteorites. Applying the same chemical-mineralogical principles that he used with terrestrial rocks, he gave the stony meteorites a rational classification, based on the study of a great many falls, many of which were new and had occurred in the territories of the French Union. The specimens collected by A. Lacroix over a period of more than fifty years have considerably enriched the mineralogy collection of the Paris Museum of Natural History. As to the petrography collection, he himself created it; with representatives of almost every known rock type, each accompanied by a chemical analysis and thin section, it is a working tool second to none.

A. Lacroix was a fearless traveler. His many assignments took him to various regions of the earth: Scotland, England, Ireland, Scandinavia, North America (both Canada and U.S.A., where he particularly visited the Atlantic Coast, the Great Lakes, the Rocky Mountains, the Yellowstone Park, Colorado), Germany, Greece, Asia Minor, Japan, Malaya, Java. He was a pioneer in colonial mineralogy. He visited Martinique, Guadeloupe, Guinea, Madagascar, and Indochina. The observations he brought back on geology, mineralogy, and vulcanology proved to be of great theoretical and practical significance. Notably, we owe him the discovery and study of the Madagascar uranium minerals.

Finally, A. Lacroix felt a great inclination for the history of sciences. He was given an opportunity to contribute to the latter in fulfilling his duties of Secretary of the Academy of Sciences, one of which was to write up the biographies of deceased members of the Academy. To this obligation of his, we owe four volumes of fascinating studies, entitled "Figures

de Savants," on the life and work of many French geologists, mineralogists, and naturalists.

From the start the originality and power of A. Lacroix's work was recognized by scientific circles. He was a "Grand Officier" of the Legion of Honor, belonged to all the Academies, had received honorary memberships and doctorates *honoris causa* from about sixty universities, foreign institutes, and learned societies. He was a correspondent of the New York Academy of Sciences since February 17, 1899; honorary member of the same academy since December 20, 1909; correspondent of the Academy of Natural Sciences of Philadelphia since January 16, 1923; correspondent of the Mineralogical Society of America since December 27, 1926; honorary member of the New York Mineralogical Club since September 16, 1923; correspondent of the American Museum of Natural History in New York. He had been awarded several famous medals; he was the third Penrose Medalist.

The last years of his life were saddened by a cruel blow, the loss of his wife, on December 22, 1944. Madame Lacroix had been his faithful companion and devoted coworker of many years, and she had accompanied him on all his travels.

Highly conscientious, open minded, just, kind, friendly to everyone, a man with a very keen mind and a sense of humor slightly ironical at times, A. Lacroix aroused a deep loyalty and a deferential devotion in his students and colleagues. He will remain one of the outstanding figures of French thought.

SELECTED BIBLIOGRAPHY

(The complete bibliography numbers 664 titles.)

A. BOOKS

1. Les minéraux des roches (with Aug. Michel-Lévy)—1 vol. Paris (1888), 334 p. 218 figs.
2. Tableaux des minéraux des roches (with Aug. Michel-Lévy)—1 vol. Paris (1889). 40 p.
3. Les enclaves des roches volcaniques—1 vol. Mâcon (1893), 770 p. 35 figs.
4. Minéralogie de la France et de ses Colonies, 5 vols. Paris
 vol. I, 1893–1895, 724 p.
 vol. II, 1896–1897, 804 p.
 vol. III, 1901, 400 p. and 1904, 416 p.
 vol. IV, 1910, 920 p.
 vol. V, 1913, 501 p.
6. La Montagne Pelée après ses éruptions avec observations sur les éruptions du Vésuve en 1879 et en 1906,—1 vol. Paris (1908), 136 p.
6. La Montagne Pelée et ses éruptions, 1 vol. Paris (1904), 662 p.
7. Minéralogie de Madagascar, 3 vol. (Paris).
 vol. I, 1922, 624 p.
 vol. II, 1922, 694 p.
 vol. III, 1923, 450 p.

8. Déodat Dolomieu, Membre de l'Institut National (1750-1801), 2 vols. Paris (1921), vol. I, 255 p. vol. II, 322 p.
9. Le volcan actif de la Réunion et ses produits. 1 vol. Paris (1936), 297 p.
10. Le volcan actif de l'île de la Réunion (supplément) et celui de la Grande Comore.—1 vol. Paris (1938), 57 p.
11. Figures de Savants.—Reproduction parfois complète des notices historiques lues aux séances annuelles de l'Académie des Sciences avec addition de quelques autres notices.
 - vol. I., Paris (1932), 325 p.
 - vol. II., Paris (1932), 357 p.
 - vol. III., Paris (1938), 213 p.
 - vol. IV., Paris (1938), 259 p.

B. PAPERS

12. Sur les inclusions de la phlogopite de Templeton (Canada): *Bull. Soc. fr. Min.*, **8** (1885), p. 99.
13. Sur une roche à amphibole sodifère (riebeckite), astrophyllite, pyrochlore et zircon du Colorado: *C.R. Acad. Sc.*, **109** (1889), p. 39.
14. Contribution à l'étude des gneiss à pyroxène et des roches à wernerite: Thèse, *Bull. Soc. fr. Min.*, **12** (1889), p. 83-307.
15. Sur la syénite éololithique de Montréal (Canada) et sur les modifications de contact endomorphes et exomorphes de cette roche: *C.R. Acad. Sc.*, **110** (1890), p. 1152.
16. Etude minéralogique de la lherzolite des Pyrénées et de ses phénomènes de contact: *Nouv. Arch. Museum.* **6** (1894), p. 209-308. 6 pl.
17. Etude sur le métamorphisme de contact des roches volcaniques: *Mém. Savants Etrangers*, **31** (1894), p. 1-88.
18. Les phénomènes de contact de la lherzolite et de quelques ophites des Pyrénées: *Bull. Carte Géol. Fr.*, **6** (1895), No. 42, p. 307-446, 21 fig. 3 pl.
19. Le gypse de Paris et les minéraux qui l'accompagnent: *Nouv. Arch. Mus.* **9** (1897), p. 201-296, 9 pl.
20. Le granite des Pyrénées et ses phénomènes de contact: *Bull. Carte Géol. Fr.*, **10** (1898), p. 241-306, and **11** (1900), p. 501-504.
21. Le gabbro du Pallet et ses modifications: *Bull. Carte Géol. Fr.* **11** (1899), p. 341-395.
22. Les roches alcalines caractérisant la province pétrographique d'Ampasindava (Madagascar): *Nouv. Arch. Mus.*, (4^e série) **1** (1902), p. 1-214, 10 pl., and **5** (1903), p. 171-254, 8 pl.
23. Sur le gisement de l'autunite de St-Symphorien de Marmagne (Saône et Loire): *C.R. C. R. Séances Soc. Hist. Nat. d'Autun*, **16** (1903), p. 134-140.
24. Etude minéralogique des produits silicatés de l'éruption du Vésuve: *Nouv. Arch. Mus.*, **9** (1907), p. 1-172, 10 pl.
25. Les minéraux radioactifs de Madagascar: *C. R. Acad. Sc.*, **152** (1911), p. 559-564.
26. Les syénites néphéliniques de l'archipel de Los et leurs minéraux: *Nouv. Arch. Mus.*, (5^e série) **3**, (1911), 132 p.
27. A trip to Madagascar. The country of beryls: *Smithsonian Reports* (1913), Washington, p. 371-382.
28. Remarques au sujet de A. Day et Shepherd conclusions tirées de l'analyse du gaz du cratère du Kilaua: *C.R. Acad. Sc.*, **157** (1913), p. 1030.
29. Les latérites de la Guinée et les produits d'altération qui leur sont associés: *Nouv. Arch. Mus.*, (5^e série) **5** (1913), p. 255-358, 7 pl.
30. A propos de la tourmaline des serpentines (Madagascar): *Bull. Soc. Fr. Min.*, **37** (1914), p. 75-76.

31. Sur l'existence de la thorianite à Madagascar: *Bull. Soc. fr. Min.*, **37** (1914), p. 176-180.
32. Sur quelques roches volcaniques mélanocrates des possessions françaises de l'Océan Indien et du Pacifique: *C.R. Acad. Sc.*, **163** (1916), p. 177-183.
33. La constitution lithologique des îles volcaniques de la Polynésie australe: *Proceedings of the Third Pan-Pacific Science Congress*, Tokyo (1926), p. 734-757.
34. L'eucrite de Béréba (Hte-Volta) et les météorites feldspathiques en général: *Arch. Mus.*, (6^e série) **1** (1926), p. 15-58.
35. La constitution lithologique des volcans du Pacifique Central Austral: *C.R. Acad. Sc.*, **185** (1927), p. 425-428.
36. La constitution lithologique des îles volcaniques de la Polynésie australe: *Mém. Acad. Sc.*, **59** (1927), p. 1-82.
37. Les météorites tombées en France et dans ses colonies et conservées au Muséum d'Histoire Naturelle, avec remarques sur la classification des météorites: *Bull. Mus.*, **33** (1907), p. 451-455.
38. La composition minéralogique et chimique des roches éruptives et particulièrement des laves mésozoïques et plus récentes de la Chine orientale: *Bull. of Geological Society of China*, **7** (1928), p. 13-59.
39. La constitution minéralogique et chimique des laves intrapacifiques. (Pacifique Central Austral): *Proceedings of Fourth Pacific Science Congress*, Java (1929), p. 941-950.
40. La Jadéite de Birmanie; les roches qu'elle constitue ou qui l'accompagnent: *Bull. Soc. fr. Min.*, **53**, p. 216-254.
41. Remarques sur les matériaux de projection des volcans et sur la genèse des roches pyroclastiques qui les constituent: *Livre jubilaire centenaire de la Soc. Géol. de Fr.*, **2** (1930), p. 431-472, 4 pl.
42. La minéralogie de la France d'Outre-Mer, départements algériens, colonies, protectorats: *Bull. Mus.*, (2^e ser.), **3** (1931), p. 137.
43. Les tectites de l'Indochine: *Arch. Mus.*, (6^e série), **8**, (1932), p. 139-236, 43 figs. 12 pl.
44. Contribution à la connaissance de la composition chimique et minéralogique des roches éruptives de l'Indochine: *Bull. du serv. Géol. de l'Indochine*, **XX**, fasc. III, (1933), p. 1-208. (*Classification et nomenclature des roches éruptives* appeared as an Introduction to this memoir.)
45. Recent observations on the mineralogical and chemical constitution of the intrapacific lavas, South Central Pacific: *Fifth Pacific Sc. Congress*, Victoria and Vancouver B. C., Canada (1933), p. 2539-2542.
46. Volcanisme et lithologie (Tibesti): *Mém. Acad. Sc.*, **61**, (1934), p. 169-366, 11 pl. 2 maps.
47. Les tectites de l'Indochine et de ses abords et celles de la Côte d'Ivoire: *Arch. Mus.*, (6^e série), **12**, (1935), p. 151-170.
48. Les gisements de phlogopite de Madagascar et les pyroxénites qui les renferment: *Annales géologiques du service des Mines de Madagascar, Tananarive*, Fasc. **XI**, (1941), p. 1-119, 12 pl. 11 figs.
49. Les glaucophanites de la Nouvelle-Calédonie et les roches qui les accompagnent, leur composition, leur genèse: *Mém. Ac. Sc.*, **65**, No 3, (1941), p. 1-103, pl. I-IV.
50. Composition minéralogique et chimique des laves des volcans de l'Océan Pacifique: *Mém. Ac. Sc.*, **63**, (1936-1939), published in 1941, p. 1-98, 9 pl. 1 map.
51. Nouvelles observations sur les fulgurites du Sahara: *Bull. du Serv. des Mines A.O.F., Dakar*, No 6, (1942), p. 25-36.
52. Les péridotites de la Nouvelle Calédonie. Leurs serpentines et leurs gîtes de nickel et de cobalt. Les gabbros qui les accompagnent: *Mém. Acad. Sc.*, **66**, (1943), p. 1-140, 13 pl. 1 map.

MEMORIAL OF ALFRED CHURCH LANE

ESPER S. LARSEN, JR.,

Harvard University, Cambridge, Mass.

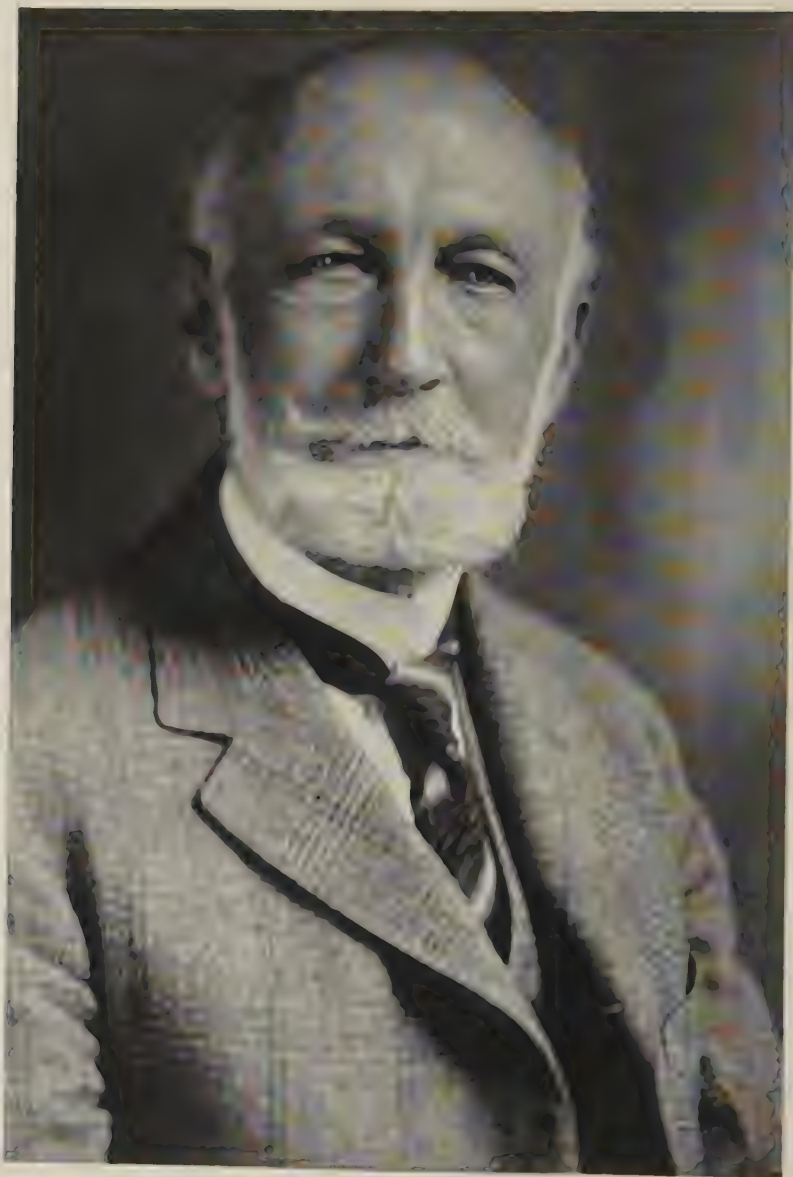
Alfred Church Lane, public-spirited citizen, teacher, geologist, died suddenly of heart attack on April 15, 1948, at the age of 85. He died in the home office of the American Institute of Mining and Metallurgical Engineers, in New York City, where he had gone to greet the returning Finn Ronne South Polar Expedition, and, in particular, his friend and former student, Doctor Robert L. Nichols. Considering his age, Dr. Lane was in good health, and he remained active and interested in his many projects until his death.

Dr. Lane was born in Boston on January 29, 1863. He received his A.B. degree at Harvard University in 1883 and the Ph.D. in 1888. As was common for students of geology in those days, he studied for two years in Germany at Heidelberg. While a student at Harvard, he was instructor in mathematics for two years, and some of his later geological work utilized his mathematical knowledge. After receiving his doctorate he worked for one year on the U. S. Geological Survey, and then joined the staff of the Michigan Geological Survey and was appointed State Geologist in 1899. In 1909, he was made Pearson Professor of Geology and Mineralogy at Tufts College, from which position he resigned in 1935 in protest against the teacher's oath of Massachusetts. During the first world war he was head of the Department of Mining at the A.E.F. University at Beaune.

He contributed much to geology and mining in Michigan. While in Michigan he studied mine and connate waters and continued his interest in these subjects to his death.

He was interested in the quantitative treatment of geological problems and some of his contributions were mathematical, notably his application of the theory of the conduction of heat to geological problems, his theoretical studies of the grain size in igneous rocks, and his work on determining geological time.

Probably his most important contribution to geology was made as Chairman of the Committee on the Measurement of Geologic Time of the National Research Council (1922-1946). As chairman, he wrote innumerable letters and, where possible, made regular visits to nearly everyone who was interested in geologic time. He served as a clearing house for specimens, data, methods, and ideas on his favorite subject, and he secured coöperation between men in different sciences and men in various parts of the world. He was full of ideas and enthusiasm, and he stimulated such interest that he was able to get chemical analyses,



ALFRED CHURCH LANE
1863-1948

geological work, determination of the isotopes, and other required work on many specimens. Largely through his efforts and the work of his Committee we now have an excellent, though still imperfect, time-scale for the geological column. Dr. Lane stimulated and coördinated the work of his Committee so that it became one of the most successful of those of the Research Council.

He was a member of many societies, including the A.I.M. & M.E. (Chairman, Boston Section '18), Am. Assn. Adv. Sc. (V. Pres. '06), Am. Acad. Arts and Sci. (Councilor '16-'19, Librarian; '30-'36), Geol. Soc. Am. (Pres. '31), Min. Soc. Am., Mich. Acad. Sci. (Pres. '05), and hon. member Soc. Belge de Geol. He was the first consultant in science, Library of Congress, Washington, D.C. '29-'30. He received the honorary D. Sc., Tufts College, '13, and in 1940 Tufts College awarded him the Ballou Medal for distinguished service to education and the Nation.

Dr. Lane was active in religious work, and his closest friends knew, admired, and loved him as a true Christian. He was always interested in, helpful to, and thoughtful of the younger men, by whom he was especially loved. He was interested in Boy Scout work and during World War II, when young men were not available as scout leaders, he, though past eighty years old, acted as scout leader until the younger scouts became too strenuous for him, and his wife persuaded him to give up scout work. For his services to the Boy Scouts of America, he was awarded the Silver Beaver. He was a leader in promoting good government in his home community and in the Nation and was greatly interested in international affairs, and, in particular, in World peace and international coöperation. He was fond of speaking before public gatherings and of publishing short articles, which might be on religion, politics, world affairs, or popular science. When he made his visits to his friends, he carried a small handbag from which he might produce a copy of a recent popular article by himself or someone else, a few letters from Europe, India, or elsewhere, a few rock specimens for age determination, and various other materials.

Dr. Lane was the author of 1,087 publications, and they show his versatility and wide interests as they cover the range of science, religion, local and national politics, economics, world affairs, and other subjects. Most of his shorter popular papers appeared in the newspapers or periodicals. Many of his popular articles were on scientific subjects but the wide range is shown by the following titles: "Tariff on Books", "Buying a Home", "Money", "Skiing in Earlier Days", "To Prevent War", "On Sidewalks", and "This Tariff Problem". He published some poems.

His scientific publications were chiefly in the broad field of geology but some were in astronomy, mathematics, and physics. In addition to his longer scientific articles, he published many short articles and dis-

cussions. In the selected bibliography at the end of this paper, only a few of Dr. Lane's more important publications on subjects related to Mineralogy and Petrology are listed.

SELECTED BIBLIOGRAPHY

- The Geology of Nahant: *Boston Soc. Nat. Hist., Proc.*, **24**, 91-95 (1889).
 (with Keller, H. F., and Sharpless, F. F.) Notes on Michigan minerals: *Am. Jour. Sci.*, 3rd ser., **42**, 499-508 (1891).
 Chloritoid von Champion, Michigan, U.S.A.: *Zeits. Kryst.*, **19**, 383-385 (1891).
 Geological report on Isle Royal, Michigan: *Mich. Geol. Survey*, **6**, pt. 1, 281 pp. (1898).
 Studies of the grain of igneous intrusives: *Geol. Soc. Amer., Bull.*, **14**, 369-384 (1903).
 Porphyritic appearance of rocks: *Geol. Soc. Amer., Bull.*, **14**, 385-406 (1903).
 The role of possible eutectics in rock magmas: *Jour. Geol.*, **12**, 83-93 (1904).
 Wet and dry differentiation of igneous rocks: *Tufts College Studies*, **3**, No. 1, 39-53 (1910).
 (with S. Powers) Magmatic differentiation in effusive rocks: *Am. Inst. Min. Eng., Bull.*, **110**, 535-548 (1916).
 Prismatic cleavage in beryl: *Am. Mineral.*, **3**, 47 (1918).
 Segregation granites: *Jour. Geol.*, **30**, 162-166 (1922).
 The philosophic classification of mineral structure: *Am. Mineral.*, **16**, 305-309 (1931).
 Size of batholiths: *Geol. Soc. Amer., Bull.*, **42**, 813-824 (1931).
 Entopotropism: *Geol. Soc. Amer., Bull.*, **43**, 313-330 (1932).
 (and others) Reports of the committee on the measurement of geologic time: *Nat. Research Council, Div. Geol. and Geog., An. Rept.* 1931, (1932); 1932, app. **H** (1933); 1934, app. **K**, 1934-5, app. **H** (1935); 1935-6, app. **K** (1936); 1936-7, app. **A** (1937); 1937-8, app. **S** (1938); 1938-9, app. **A** (1939); 1939-40, app. **G** (1940); 1940-1, app. **E** (1941); 1941-2, app. **F** (1942); 1942-3, app. **F** (1943).
 (and Bennett, W. R.) Location of faults by radioactivity: *Beitrag. Angew. Geophysik*, Bd. **4**, 353-357 (1934).
 Fivefold check of uranium age?: *Am. Mineral.*, **19**, 1-13 (1934).
 (and Urry, W. D.) Age by the helium method: I, Keweenawan: *Geol. Soc. Amer., Bull.*, **46**, 1100-1120 (1935).
 Rating the geologic clock: *16th Internat. Geol. Cong.*, 1933, *Rept.* **1**, 145-167 (1936).
 Measurement of geologic time, its difficulties: *Smithsonian Inst. Ann. Rept.* 1937, 235-254 (1938).
 The evolution of the hydrosphere: *Am. Jour. Sci.*, **243-A**, 393-398 (1945).
 How the earth shows its age: *Science in Progress*, 107-146 (1940).
 Various pages on mineralogy and geology in "Lefax".

MEMORIAL OF JAMES GREENFIELD MANCHESTER

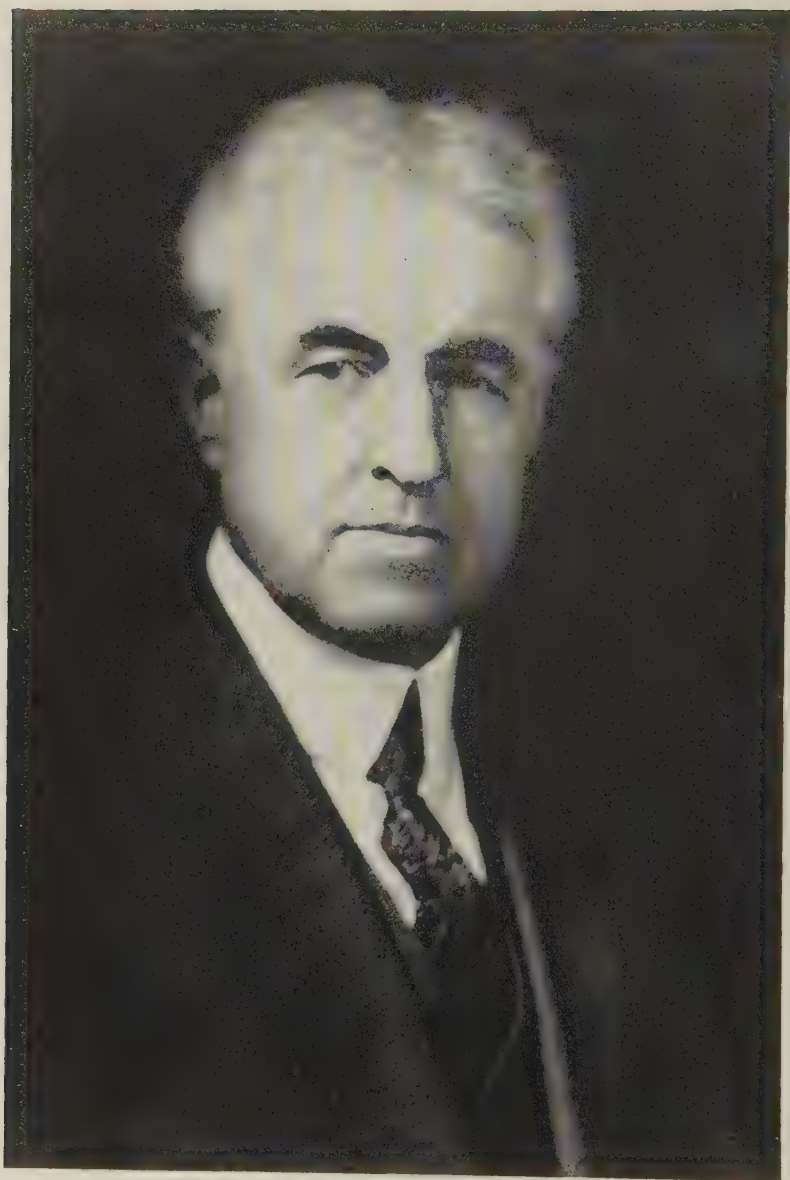
GILMAN S. STANTON,
New York City.

James G. Manchester, born in Fall River, Massachusetts, on September 20, 1871, was a man whose love of fine mineral specimens found expression in a lifetime of devoted service to his fellow collectors and enthusiasts. He was not of those favored few who, born to wealth, could expand his interests without thought of cost, but one of the many who through continuous effort achieved success not only in his career of business, but in his mineralogical avocation as well. As a young man, he studied typing and stenography, in which he became so proficient that his beautiful and intricate patterns and designs created by means of type-written characters won for him at the Columbian Exposition in 1893 the award of best in the United States. At the request of his close friend, Reverend Percy S. Grant, Rector of the Church of the Ascension in New York City, he moved there to act as treasurer of the church. Soon thereafter he became Assistant Treasurer of the New York Mutual Life Insurance Company, and later the Assistant Manager of their Real Estate Division, which he efficiently organized and systematized.

Having adopted mineralogy as his hobby, he rapidly became an enthusiastic and vigorous collector with an unerring eye for good specimens and an indefatigable zeal for extracting them. His appreciation of fine minerals did not degenerate into mere acquisitiveness, and he was constantly and generously bestowing choice specimens and collections upon his fortunate friends and associates. A superb collection in specially designed cases was presented to the city of Fall River, where it is exhibited in the public library. Another was contributed to the American Museum of Natural History in New York City. To young people who displayed an active interest in mineralogy he gave representative species, as well as entire suites of specimens obtained at his own expense. Many eastern mineralogical museums contain choice material labeled "Gift of J. G. Manchester." His continuing advocacy of the pleasures of mineral collecting and study resulted in many lectures and well-illustrated demonstrations before clubs and high school and Boy Scout groups.

He became president of the New York Mineralogical Club, succeeding George F. Kunz, and in that capacity he was instrumental in securing many notable speakers for the Club, partly at his personal expense. Through his generosity, the organization was able to publish his careful compilation, "The Minerals of New York City and Its Environs."

Upon retirement, he spent most of his winters in St. Petersburg,



JAMES GREENFIELD MANCHESTER
1871-1948

Florida, where he interested himself in the Ballast Point locality at Tampa, famous for specimens of corals replaced by chalcedony. These he had photographed in color and cut into cabochons. The article describing these unusual chalcedony pseudomorphs after coral, published in *Rocks and Minerals* proved so popular that many additional reprints were prepared to supply the public demand. The cost of the preparation of this article as well as the reprints was borne by Mr. Manchester. He was a fellow of the American Association for the Advancement of Science, the Mineralogical Society of America, a member of the Rocks and Minerals Association, and a life member of the Ohio Archaeological and Historical Society.

By his first wife, Florence Pilkington, born July 12, 1873, died Oct. 23, 1919, he had a son James G. Manchester, Jr., born March 19, 1896, died April 4, 1943, who in turn is survived by a son, James G. Manchester III, born March 18, 1943. His second marriage was to Mrs. Clara A. Ehmer on June 14, 1923, who survives him. Mr. Manchester died on June 28, 1948, at Southampton, Long Island, at the age of seventy-six. He was a man of kindly generosity and hospitality, capable of communication to others his love of beautiful minerals.

BIBLIOGRAPHY

- Asteriated rose quartz in (Bedford) New York State: *Min. World*, **32**, 1185-1186 (1910).
New discovery of gem stones on Manhattan Island: *Abst. N. Y. Acad. Sci. An.*, **21**, 206 (1912).
The minerals of Broadway, New York City: *N. Y. Min. Club., Bull.*, **3**, 52 pp. (1914).
Famous mineral localities—Mt. Mica, Mt. Apatite and other localities in Maine: *Am. Mineral.*, **3**, 169-174 (1918). With W. T. Bather.
The minerals of the Bergen Archways (Erie Railroad open cut) Jersey City, N. J.: *Am. Mineral.*, **4**, 107-116 (1919); *N. Y. Min. Club., Bull.*, (2) **2**, 9-20 (1919).
A discovery of gem garnet (spessartite) in New York City: *Am. Mineral.*, **2**, 85-86 (1917).
With Gilman S. Stanton.
The minerals of New York City and its environs. Published by the New York Mineralogical Club, 185 pp., 127 plates, 1 map (1931).
Fifty years of mineral collecting from Maine to Florida: *Rocks and Minerals*, **15** (8), 255-260 (1940).
Collecting semi-precious stones in Florida: *Rocks and Minerals*, **16** (12), 435-454 (1941).

MEMORIAL OF LEWIS GARDNER WESTGATE

JOHN H. MELVIN, *Geological Survey, of Ohio, Columbus, Ohio.**

Lewis Gardner Westgate was born October 8, 1868, in Phenix, Rhode Island. His father, a liberal and scholarly man, attended Wesleyan University, standing second in his class, spent two years at Union Theological Seminary, and served as a Methodist minister until 1880 when he became professor of history at "Old" Wesleyan. The elder Westgate died in 1885 when Lewis was sixteen years old.

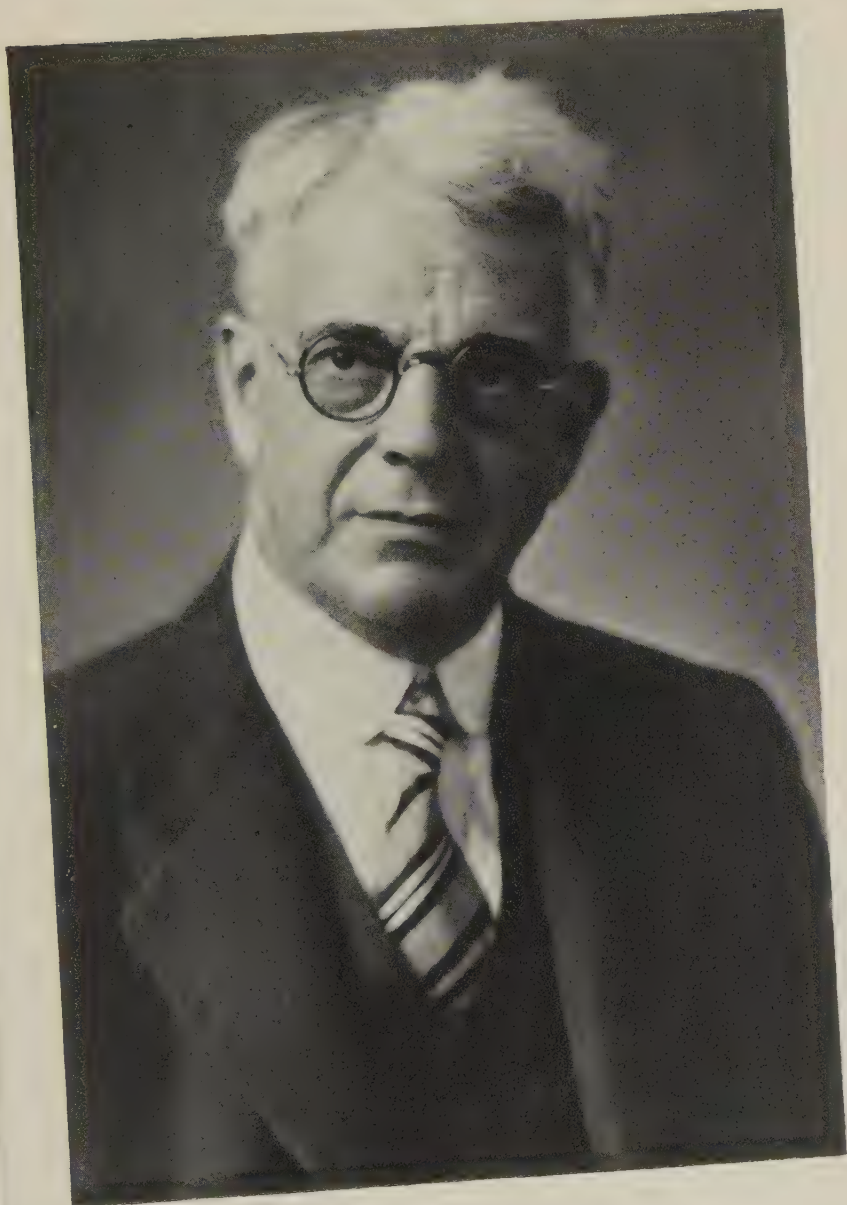
In high school young Westgate was active in a boy's scientific society, a chapter of the Agassiz Association. The collecting of plants and minerals was carried on and the reading of papers was encouraged. That this society was above the average is attested by the fact that from this small town group five men went on to professional careers in the sciences.

From 1886 to 1890 Westgate was an undergraduate at Wesleyan University. Evidently at first he was thinking seriously of following his father's footsteps into the ministry. For three months of his freshman year he was a local preacher in the Methodist Church. In his junior year, however, one of the required subjects was a course in geology taught by William North Rice. From then on geology was the main interest of his life. Accordingly, the remainder of his work at Wesleyan was devoted to geology and related sciences. However, he tells of being strongly influenced by Woodrow Wilson, then professor of history, and by Caleb T. Winchester, professor of English literature, from whom he acquired a respect for the English language and a love of English literature. He received his A. B. degree in 1890. In 1940 Wesleyan honored him with an honorary Sc.D.

Following his graduation from Wesleyan, Westgate took three years of graduate work in geology at Harvard where he became more or less a disciple of William Morris Davis. From Harvard he received the A.B. degree in 1891, the M. A. degree in 1892, and the Ph.D. degree in 1896. He was a graduate assistant at Harvard from 1891 to 1892, and at Wesleyan from 1892 to 1893.

In 1893 Westgate accepted a teaching position in the Evanston Township (Ill.) schools and continued there until 1900. On Sept. 5, 1893, he married Martha Josephine Beach. Dr. Edward L. Rice, a lifelong friend, has written, "A childhood acquaintance and a college friendship led to a married life which spanned more than fifty-five years. It was an ideal partnership to which each contributed in full measure with enough di-

* For assistance in the preparation of this memoir acknowledgment is due Dr. Arthur Bevan, Principal Geologist, Illinois Geological Survey.



LEWIS GARDNER WESTGATE
1868-1948

versity of talent and temperament to add interest, enough of community to assure the finest teamwork. Admission to the esthetic beauty and spiritual culture of their home was in itself a liberal education. He was denied the joy of fatherhood; but to scores, perhaps hundreds, of his students and younger colleagues he became 'Uncle Lewie' and note that Mrs. Westgate is no less 'Aunt Jo,' for the adopted nephews and nieces passed from the laboratory to the home."

In 1900 Dr. Westgate came to Ohio Wesleyan University as professor of geology and there he served for the remainder of his life. He retired with the title of emeritus professor of geology in 1939 but when younger men were called away during the early days of World War II he again took up his old duties. Failing eyesight finally forced him from the classroom in 1944 after over half a century of teaching.

Dr. Westgate spent many summers on work of the United States Geological Survey in both the western states and in Alaska. With this organization he was assistant geologist 1912-1919 and associate geologist 1919-1935. He also carried on work for the Geological Survey of Ohio, completing his "Geology of Delaware County" in 1926 and leaving an almost completed report on Adams County.

He was a fellow of The Mineralogical Society of America and The Geological Society of America (Vice-President in 1926). He was a member of the Ohio Academy of Science (President in 1910-11), Sigma Xi, Phi Beta Kappa, Omicron Delta Kappa, and Psi Upsilon.

Throughout his long professional career Dr. Westgate was a practicing "field geologist" to quote him, and that his contributions have been substantial is attested by the appended bibliography. Of even greater importance perhaps, has been his influence as an educator and as an inspirer of younger people. His periodic chapel talks before the entire college were looked forward to by student body and faculty alike. Nor were either disappointed for Lewis's thought-provoking addresses led to reflection and self-examination by those in all walks of life. His educational and philosophical writings had a similar effect. In his teaching too, humor, philosophy, and clarity of description combined to make each lecture an enjoyable experience. He was interested in more than geology; he strove to teach his students to think for themselves and in the end to be truly educated men and women. In this he was exceptionally successful.

Dr. Westgate had many other interests. His paintings, his iris garden, his block print Christmas cards, his excellent library, and his activities in sponsoring good government for his community all testify to his many abilities.

In philosophy he found his greatest satisfaction. In 1944 glaucoma

caused complete loss of sight. Sometime later in a paper titled "My Road To Evolutionary Naturalism" he set down the philosophy which he had developed during a long lifetime of careful observation and honest thinking, a philosophy which he believed to be held by many men of science, one which he believed to be expressed in the lines from Wordsworth's Tintern Abbey.

I have felt

A presence that disturbs me with the joy
Of elevated thoughts; a sense sublime
Of something far more deeply interfused,
Whose dwelling is the light of setting suns,
And the round ocean and the living air,
And the blue sky, and in the mind of man:
A motion and a spirit, that impels
All thinking things, all objects of all thought,
And rolls through all things.

Dr. Lewis G. Westgate died on March 30, 1948, at Delaware Ohio. He is survived by his wife, and by countless adopted "nieces" and "nephews," his contribution to man's fight for a better world.

BIBLIOGRAPHY

- (1893) The geographic developments of the eastern part of the Mississippi drainage system: *Am. Geologist*, **11**, 245-260.
- (1894) The mineralogic characters of certain New Jersey limestones: *Am. Geologist*, **14**, 308-313.
- (1894) The age of the crystalline limestones of Warren County, New Jersey: *Am. Geologist*, **14**, 369-379.
- (1896) The geology of the northern part of Jenny Jump Mountain, in Warren County, New Jersey: *New Jersey Geol. Survey, Annual Report for 1895*, 21-61.
- (1899) A granite gneiss in central Connecticut: *Journal Geology*, **7**, 638-654.
- (1905) The Twin Lakes glaciated area, Colorado: *Journal Geology*, **13**, 285-312.
- (1907) Abrasion by glaciers, rivers, and waves: *Journal Geology*, **15**, 113-120.
- (1912) The geological progress of twenty-five years: *Ohio State Academy Science, Proceedings*, **6**, 20-42.
- (1913) (And E. B. Branson) The later Cenozoic history of the Wind River Mountains, Wyoming: *Journal Geology*, **21**, 142-159.
- (1920) Deposits of iron ore near Stanford, Montana: *U. S. Geol. Survey, Bull.* **715**, 85-92.
- (1921) Ore deposits of the Salmon River district, Portland Canal region, Alaska: *U. S. Geol. Survey, Bull.* **722**, 117-140.
- (1921) Deposits of chromite in eastern Oregon: *U. S. Geol. Survey, Bull.* **725**, 37-60.
- (1921) Deposits of chromite in Stillwater and Sweet Grass counties, Montana: *U. S. Geol. Survey, Bull.* **725**, 67-84.
- (1926) Geology of Delaware County (Ohio): *Geol. Survey, of Ohio 4th series, Bull.* **30**, 147 pages.
- (1927) (And Adolph Knopf) Geology of Pioche, Nevada, and vicinity: *Am. Institute Mining Eng., Transactions*, **25**, 816-836.

- (1929) William N. Rice, 1845-1928: *Science*, n.s., **69**, 31-32.
- (1929) Memorial of William North Rice: *Geol. Soc. Am., Bull.* **40**, 50-57.
- (1930) White clays or upland flat soils of southern Ohio: *Geol. Soc. Am., Bull.* **41**, 329-340.
- (1932) (And Adolph Knopf and Joseph L. Gillson) Geology and ore deposits of the Pioche district, Nevada: *U. S. Geol. Survey, Professional Paper* **171**, 79 pages.
- (1933) (And Richard P. Fischer) Bone beds and crinoidal sands of the Delaware limestone of central Ohio: *Geol. Soc. Am., Bull.*, **44**, 1161-1172.
- (1936) Memorial of Eugene Wesley Shaw: *Geol. Soc. Am., Proceedings for 1935*, 311-318.
- (1940) Errors in scientific method: glacial geology: *Scientific Monthly*, **51**, 299-309.
- (1942) Newberry on the Ohio drift: *Ohio Journal Science*, **42**, 215-219.
- (1943) Man's long story: *Scientific Monthly*, **57**, 155-165.

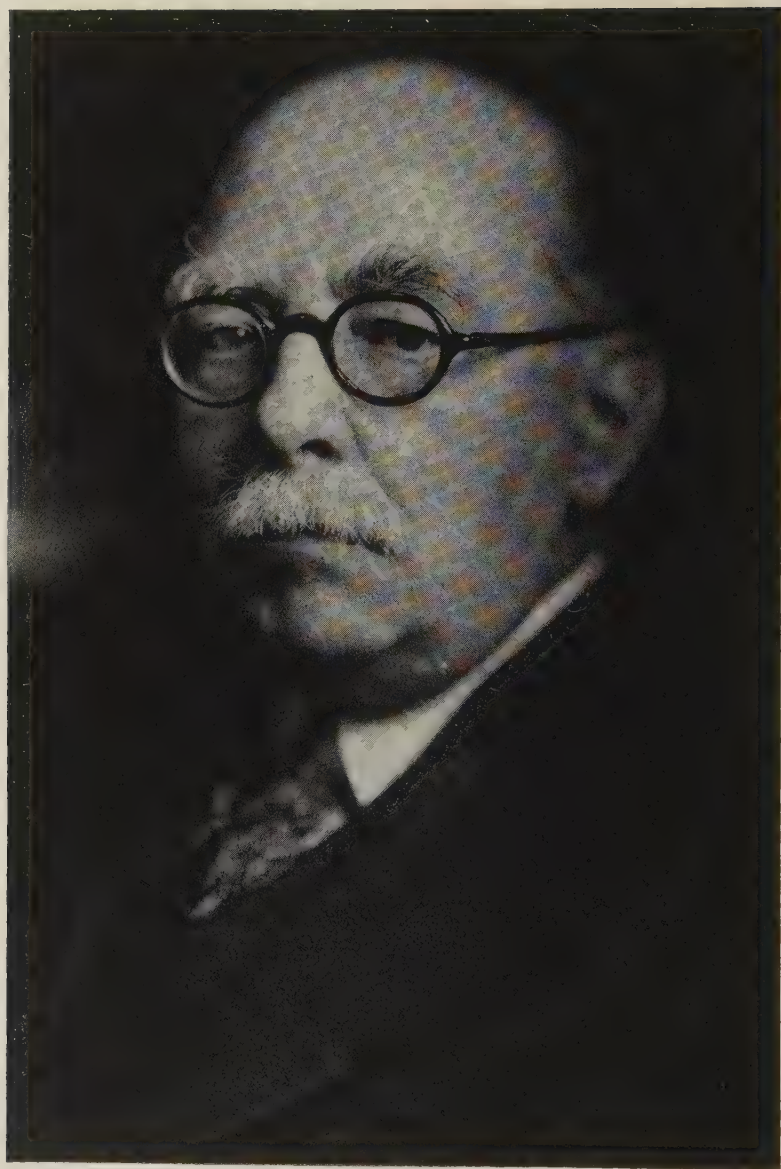
MEMORIAL OF HERBERT PERCY WHITLOCK

FREDERICK H. POUGH, *The American Museum of Natural History.*
New York, N. Y.

For twenty-three years, Herbert P. Whitlock served as Curator of Mineralogy at The American Museum of Natural History, where he had charge of one of the finest mineral and gem collections in the world. In this role his service to mineralogy had several facets, both through the popularization of the subject among laymen who happened by accident to enter Morgan Hall, but more especially by his stimulation and encouragement of an interest in the subject among impressionable youths, many of whom went on to specialize in geological studies in their later academic work. Along with this time-consuming educational work he carried on his writings, predominantly scientific in the early phases but increasingly directed at popular education in his latter years.

Herbert Whitlock was born July 31, 1868, in New York City, the son of Thomas and Caroline V. (Hull) Whitlock. He attended private school in New York and graduated from the Charlier Institute in 1884. He then went to the School of Mines at Columbia University, where he took an engineering course, with a few lectures in geology and mineralogy. He studied mineralogy under Professor Alfred E. Moses and did so well that, after his graduation in 1889 with the degree of C. E., he was offered an assistantship in mineralogy, to help out in Professor Moses' laboratory and classes. He held this position until 1901. A position as assistant in mineralogy in the New York State Museum was then offered to him and he served in the junior capacity at Albany from 1901 to 1904. He then was appointed Mineralogist, a rank he held for twelve years. During this period he worked actively with the mineral collection of the State Museum, rearranging the displays and designing new cases to display the minerals to better advantage. He considered the technique of display one of his specialties, and so listed himself in reference books. At the same time he was very active in mineralogical studies and published some of his best work. His second paper after going to Albany was the now long out of print, but still very useful, guide to mineral localities of New York. He wrote numerous studies of a morphological and crystallographic nature, specializing particularly on calcite. He taught himself to use the gnomonic projection methods and the two-circle goniometer of Victor Goldschmidt, and all of his life was rather proud of the fact that he had attained his position in mineralogy without further academic study and a Ph.D. degree. He became State Mineralogist in 1916 and remained in Albany with this title until 1918.

In 1918, the sudden death of L. P. Gratacap created a vacancy in the



HERBERT PERCY WHITLOCK
1868-1948

Department of Mineralogy at The American Museum of Natural History and Mr. Whitlock resigned his state position to accept an appointment as Curator and Chairman of the department in New York. This new job soon proved to be rather different in its requirements, and he found it increasingly difficult to continue his research work and fulfill the demands of the public at the same time. Feeling that as the Curator of a great public collection he owed it to the visitors to tell them interestingly the many things he knew about minerals, and to answer their questions and identify their unknowns, he concentrated increasingly upon lecturing, popular writing, and educational work.

Mr. Whitlock was for 23 years the Curator of the mineral collection before he retired in 1941 to become Curator Emeritus, and he retained his affiliation with the department as Research Associate in Jade. His interest in jade was stimulated by the bequest to the Museum of the I. Wyman Drummond Collection of Jade and Oriental art. Originally feeling that it was his responsibility to inform himself upon the subject, he soon became so interested in the symbolism and mythology illustrated by carvings in jade, that he was recognized as an authority upon this subject. Many of his later publications deal with this subject, and he was honored by an appointment as Honorary Curator of the Wadsworth Atheneum and Morgan Memorial of Hartford, Connecticut.

In addition to the Drummond Collection, the Museum received one of its most notable gifts, the William Boyce Thompson collection of minerals and jade, during Mr. Whitlock's term. He took great interest in the arrangement of the mineral display and in the proper background and setting for the many notable examples. He also designed new gem cases and supervised the reinstallation of that important collection, using new types of blown glass holders developed with the help of the Museum's staff. Several other important additions were made to the collections during his period of tenure, including the Schettler emerald, the DeLong ruby, and most recently, the endowment that accompanies the Thompson Collection.

Mr. Whitlock's many kindnesses and feeling of public responsibility can best be illustrated by a few examples. He gave "surplus" minerals to boy scouts (and any others who requested the privilege), who could identify the specimens from a box he kept in his office. Since the Museum sent out no expeditions and as Mr. Whitlock did not enjoy travel in automobiles, his field work was very limited, the "surplus stuff" was actually pound material purchased at his own expense from various mineral supply houses. He regularly spent Saturday morning in the Morgan Hall to answer all sorts of questions from the visitors. For many

years he ran spring and fall series of lectures on Saturday afternoons, one on jade, the other gems, and these were filled year after year, by the general public as well as jewelers.

He was very popular among his fellow curators and though he often seemed a little strange with his courtly old world manners, he was generally admired through the Museum for his charm and friendliness. He was plagued in his later years by rheumatism and failing eyesight, but he did not lose his interest in his subject and his fellows, nor his sense of humor. Though he was prone to correct people who addressed him as "doctor" he often used to say that if he ever caught a college president at it, he was going to take him up on it at once, and see what kind of a degree he got.

Mr. Whitlock's accomplishments led to the reception of many other honors, even though he never trapped himself into an honorary doctorate. He was Secretary of our Society from 1920 to 1922, and was elected President in 1933. He was a Fellow of The Geological Society of America, and of the American Academy of Arts and Sciences, a Member of the Mineralogical Society of Great Britain, the New York Academy of Sciences, and of the New York Mineralogical Club. He was Secretary and President of the latter organization and was made an Honorary Member after his retirement from the museum curatorship. His contributions to the Museum made him a Patron of the Museum in 1930.

The death of Mr. Whitlock has taken another of the popular figures of the less specialized type of mineralogist from American science. He felt himself that too many of the younger mineralogists were so specialized that they had little love for minerals and little chance to become well acquainted with them, when they devoted themselves to the microscope or to photographic reproductions of *x*-ray patterns. Though not a field man in his later years, Mr. Whitlock had the love for minerals that is essential in good teachers who inspire others to go into the science. His general background and earlier training made him a leader at sight identification, a first requisite for the position he held so successfully for so many years. The failing eyesight which came with his advancing years was probably felt most keenly because it prevented him from seeing and loving the beauties of the well crystallized mineral specimens that had been his joy for so many years. To his friends and relatives, and to the hundreds he has helped and inspired, Mr. Whitlock's passing leaves another hole that cannot be filled, but a warm feeling too, when we think of him, of pleasure in his memory and in the knowledge that we carry on some of his appreciation of the beauty of minerals, that they enthuse us as they did him for so many years.

BIBLIOGRAPHY

1902. Guide to the mineralogic collections of The New York State Museum: *N. Y. State Museum*, **B 58**, 3-147.
1903. List of New York mineral localities: *N. Y. State Museum*, **B 70**, 108 pp.
1905. Contributions from the mineralogic laboratory: *N. Y. State Museum*, **B 98**, 36 pp.
- 1905a. Minerals not commercially important: *N. Y. State Museum*, **An Rp 57**, 180-192.
1906. Books of reference on geology and paleontology: *Cong. Arts and Sc.* (St. Louis, 1904) **4**, 757-759.
1907. Minerals from Lyon Mountain, Clinton Co. N. Y.: *N. Y. State Museum*, **B 107**, 55-96.
- 1907a. Kalkspat von Lyon Mountain, Clinton Co. N. Y.: *Zeit. Kryst.*, **43**, 321-330.
- 1907b. Some new crystallographic combinations of calcite from West Paterson, N. J.: *Am. Jour. Sci.* (4) **24**, 426-428.
1909. Some parallel groupings of calcite crystals from the New Jersey trap region: *N. Y. State Museum*, **B 133**, 217-22.
1910. Calcites of New York: *N. Y. State Museum, Mem.* **13**, 190 pp.
- 1910a. Contributions to mineralogy: *N. Y. State Museum*, **B 140**, 197-203.
- 1910b. Crystallographic notes on datolite and apophyllite from Bergen Hill, N. J., and calcite crystals from Kelleys Island, Ohio: *Sch. Mines*, **Q 31**, 320-345; **32**, 51-92.
1912. Recent mineral occurrences in New York City and vicinity: *N. Y. State Museum*, **B 158**, 183-187.
- 1912a. Crystallographic tables: *Science*, n.s., **35**, 819-820.
1913. The Mount Morris meteorite: *N. Y. State Museum*, **B 164**, 78-79.
1915. A critical discussion of the crystal forms of calcite: *Am. Ac. Arts, Pr.* **50**, 289-352.
1916. Guide to the mineral collection: The University of the State of New York. (From the 12th Report of the Director of the Science Division).
1917. Presentation of crystallography as a museum installation: *Proceedings, Amer. Assoc. of Museums*, vol. **XI**.
1918. René Just Haüy and his influence: *Am. Mineral.*, **3**, No. 6, 92-98.
1919. Crystallographic studies of barite: *The Univ. of the State of New York*.
1919. Crystallographic notes on pyrite: *Am. Mineral.*, **4**, No. 5, 31-32, pl. 4; **4**, No. 6, 67-68.
1920. A model for demonstrating crystal structure: *Am. Jour. Sci.*, **XLIX**, 259-264 (April).
1921. How diamonds are polished: *Natural History*, **XXI**, No. 3, 1-5.
1922. A list of new crystal forms of minerals: *Bulletin, The American Museum of Natural History*, **XLVI**, art. II, 89-278.
1924. Crystallographic studies of pyrite: *Am. Mus. Novitates*, No. **112**, 1-8.
1925. The mimicry of minerals: *Natural History*, **XXV**, No. 2, 156-161.
1925. Crystallographic studies of apatite: *Am. Mus. Novitates*, No. **190**, 1-4.
1926. The art of the lapidary: *Guide Leaflet*, Series No. 65, *Am. Mus. Nat. Hist.*, 1-29 (December).
1926. The collection of minerals in The American Museum of Natural History: *Guide Leaflet* No. **49**, 1-32 (third edition).
1927. A study of the crystallography of the calcites of the New Jersey diabase region: *Bull. Am. Mus. Nat. Hist.*, **LVI**, art. V, 351-377.
1927. A museum pilgrimage: *Natural History*, **XXVII**, No. 1, 93-104.
1928. Symmetry in nature: *Natural History*, **XXVIII**, No. 2, 161-168.
1928. What is a gem? *Natural History*, **XXVIII**, No. 6, 605-616.
1929. A crystallographic note on greenockite from West Paterson, New Jersey: *Am. Mus. Novitates*, No. **372**, 1-2.

1929. Danburite from Obira, Japan: *Am. Mus. Novitates*, No. 374, 1-10.
1929. Weather prophets of the sky: *Natural History*, **XXIX**, No. 3, 251-260.
1933. Opals of the Morgan Gem Collection: *Rocks and Minerals*, **8**, No. 1, 12-13.
1934. A century of progress in crystallography: *Am. Mineral.*, **19**, No. 3, 93-100.
1934. Jade, Amber, and Ivory: *Natural History*, **XXXIV**, No. 5, 458-472.
1934. Jade and the antique use of gems: *Guide Leaflet*, Series No. 79, 1-23 (A.M.N.H.).
1934. Adventures of a museum curator: *Rocks and Minerals*, **9**, No. 12, 177-178.
1935. The Netsuke of Japan: *Guide Leaflet*, Series No. 87, 121-131 (A.M.N.H.)
1936. The Story of the Gems: Published by Lee Furman, 206 pp.
- The Story of Jade (with Martin Ehrmann): Emerson Books, Inc. (Promised for 1949).

PROCEEDINGS OF THE TWENTY-NINTH ANNUAL MEETING OF THE MINERALOGICAL SOCIETY OF AMERICA AT NEW YORK, N. Y.

C. S. HURLBUT, JR., *Secretary*.

The twenty-ninth annual meeting of the Society, which was held at the Hotel Pennsylvania, New York, on November 11-13, 1948, was attended by 232 members and fellows. Scientific sessions were held in the afternoon on November 11th and in the morning on November 12th and 13th, at which thirty-four papers were presented. Five additional papers were given in the afternoon on November 12th at a Conference on *The Teaching of Crystallography*, prior to which the retiring President, Martin A. Peacock, addressed the Society on *Prospect of Mineralogy*.

The annual luncheon of the Society on November 12th was the best attended of any in the history of the Society; 190 fellows, members and guests were present. Following the luncheon George Tunell introduced the recipient of the Roebling Medal, W. Lawrence Bragg of the Cavendish Laboratory, Cambridge, England. Sir Lawrence is the eighth recipient of the medal and the second from England to receive this award. On the following pages are given the reports of the officers for the year ending October 31, 1948, as read before the Council at its meeting on November 10, 1948.

REPORT OF THE SECRETARY

To the Council of The Mineralogical Society of America:

SOCIETY ACTIVITIES

During the past year two committees, in addition to those handling the routine business of the Society, have been active. One of these, with Clifford Frondel as Chairman, has been considering the desirability of awarding a medal for a single outstanding contribution to the Science of Mineralogy. The other is the Committee on Mineralogical Research, composed of ten Fellows with Michael Fleischer as Chairman. Its function is to bring mineralogical science to the attention of other groups by:

1. Pointing out recent accomplishments.
2. Outlining major work in progress.
3. Looking to the future with the hope of stimulating research and directing it in certain channels.

The reports of both committees will be published in a future issue of *The American Mineralogist*.

In June of 1948 Michael Fleischer was appointed for three years as the representative of The Mineralogical Society to the National Research Council.

Following action taken by the Council in 1947, The Mineralogical Society of America became a member organization of The American Geological Institute, and two of its Fellows, Paul F. Kerr and Earl Ingerson, have been appointed Directors of the Institute.

During the summer of 1948 the First Congress of the International Union of Crystallography was held at Harvard University. The Mineralogical Society of America was one of the sponsoring organizations.

The Society was represented by several Fellows at the 18th International Geological Congress held in England during the summer of 1948.

ELECTION OF OFFICERS AND FELLOWS

Four hundred and sixty ballots were cast in the election of officers: 310 by members and 150 by fellows of the Society. The officers elected are:

President: John W. Gruner, University of Minnesota, Minneapolis, Minnesota.

Vice-President: J. D. H. Donnay, The Johns Hopkins University, Baltimore, Maryland.

Secretary: C. S. Hurlbut, Jr., Harvard University, Cambridge, Massachusetts.

Treasurer: Earl Ingerson, U. S. Geological Survey, Washington, D. C.

Editor: Walter F. Hunt, University of Michigan, Ann Arbor, Michigan.

Councilor (1949-1952): Lewis S. Ramsdell, University of Michigan, Ann Arbor, Michigan.

According to the provisions of the constitution the following have been elected to fellowship:

Helen Blair Barlett, AC Spark Plug Company, Flint, Michigan.

William Howard Barnes, National Research Council, Ottawa, Canada.

Thomas Fulcher Bates, Pennsylvania State College, State College, Pennsylvania.

G. F. Claringbull, British Museum (Natural History), London, England.

Julien Drugman, Uccle (Brabant), Belgium.

Jesse Harlan Johnson, Colorado School of Mines, Golden, Colorado.

G. G. Lemmlein, Institute of Crystallography, Academy of Science, U.S.S.R.

Marie Louise Lindberg, U. S. Geological Survey, Washington, D. C.

Arthur Montgomery, Boston University, Boston, Massachusetts.

Hans Jurie Nel, Geological Survey of South Africa, Pretoria, Union of South Africa.

Willard Hall Parsons, Wayne University, Detroit, Michigan.

Arthur Lindo Patterson, Bryn Mawr College, Bryn Mawr, Pennsylvania.

Raymond Pepinsky, Alabama Polytechnic Institute, Auburn, Alabama.

John Charles Rabbitt, U. S. Geological Survey, Washington, D. C.

Joseph Leon Rosenholtz, Rensselaer Polytechnic Institute, Troy, New York.

Richard Edwin Stoiber, Dartmouth College, Hanover, New Hampshire.

Elysiario Tavora, University of Brazil, Rio de Janeiro, Brazil.

Benno Wasserstein, Geological Survey, Pretoria, Union of South Africa.

Herman Yagoda, National Institute of Health, Bethesda, Maryland.

CHANGES IN THE BY-LAWS

On the recent ballot fellows and members were asked to vote on the following proposed changes in the By-Laws:

1. That the last three sentences of Article II, Section 1 be changed

From

The annual dues for fellows shall be five dollars (\$5), payable at or before the annual meeting in advance. The annual dues for fellows of the Mineralogical Society of America who also pay dues as fellows of the Geological Society of America shall be two dollars (\$2), payable at or before the annual meeting in advance. This provision shall continue in effect as long as the Geological Society of America shall contribute funds which the Council of the Mineralogical Society of America shall consider adequate to assist in publication of the Journal of The Mineralogical Society of America.

To

The annual dues for fellows shall be five dollars (\$5), payable in January.

2. That Article II, Section 2 be changed

From

The annual dues for members shall be three dollars (\$3). No person shall be accepted as a member unless he pays the dues for the year within three months after notification of his election. The annual dues shall be payable at or before the annual meeting in advance.

To

The annual dues for members shall be four dollars (\$4), payable in January.

The first change was approved by a vote of 370 in the affirmative with 45 in the negative. The second change was approved by a vote of 398 in the affirmative with 50 in the negative.

MEMBERSHIP STATISTICS

	November 1, 1948			
	1947	1948	Gain	Loss
Correspondents	6	5	0	1
Fellows	254	270	20	4
Members	677	686	177	168
Subscribers	501	592	127	36
	—	—	—	—
	1438	1553	324	209

The above figures show a net gain of 16 fellows, 9 members and 91 subscribers. Considering the four groups together there is a total gain of 115. Thus for the sixth consecutive year there has been a steady increase in members and subscribers, bringing the grand total to 1553.

The Society lost through death one Correspondent, A. Lacroix, and four fellows: Alfred C. Lane, James G. Manchester, Lewis G. Westgate, and Herbert P. Whitlock.

Respectfully submitted,

C. S. HURLBUT, JR., *Secretary*

REPORT OF THE EDITOR FOR 1948

To the Council of the Mineralogical Society of America:

Presenting an annual editorial report for the calendar year at this time offers certain difficulties as regards particular details not encountered when meetings were held and reports given in late December. However, with five issues published and distributed and only one still in press, sufficient data are now available to give a general survey of the year's activity. By the time the Editor's report appears in print the missing data will be available and be incorporated, so that the then complete published report can be compared on the same basis as the summaries of previous years.

I think you will agree that from the standpoint of scholarly productivity the Journal for 1948 has moved forward. From present indications the volume will approach the 800 page mark a considerable increase in size (nearly 100 pages) over a year ago. In the main the policy of former years has been followed with some slight departures. For some time, in certain quarters, there has been expressed the hope that the journal might include, from time to time, a number of the more lengthy contributions. This year, as you may recall, we have included several of that type. For example, in the May-June number the first article covers 61 printed pages, and a number of other lengthy articles have appeared in other issues. Also in the matter of articles involving folded inserts, here, likewise, the attitude

has been one of liberality. Two colored plates have also added attractiveness and scientific value to the issues in which they appeared. The cost of one of these was charged against the funds of the Geological Society while the cost of the other was met by the Bausch & Lomb Optical Company. Also, in the matter of illustrations, here again the policy has been a very liberal one. In one 33-page article appearing in the July-August number 20 figures seemed necessary, 16 of which were full page illustrations.

It is the Editor's belief that all these items increase the value and effectiveness of our Journal as a national scientific publication. But it will also explain, unfortunately perhaps, why the current volume has been such an expensive one. Perhaps in this connection the question might very appropriately be asked whether the time has come to consider an increase in our working capital by advancing our subscription rates.

There seems little possibility, in the near future, at least, of reducing costs unless we limit the length of articles, eliminate folded inserts and colored plates (except when this does not involve expenditure by the Society), and reduce the number of free reprints. These measures, I am sure, would be considered retrogressive and should only be adopted as a last resort. It would seem more desirable to maintain our present standards and policies but increase somewhat our subscription price, if increased revenue is needed.*

The field that we attempt to cover is a large one, and the service rendered is by no means restricted to mineralogy in the narrow orthodox sense. To illustrate this extended service to related groups, last year the *Mineralogist* published the abstracts of 28 papers presented before The Crystallographic Society of America which was held in March, 1947. This year a joint meeting was held of The Crystallographic Society of America and The American Society of X-ray and Electron Diffraction, and a considerably longer program resulted. The 53 abstracts and five titles of this joint session, as well as the Presidential address, appeared in the November-December issue.

During the past year, there has been no heavy backlog of accumulated manuscripts under our present bimonthly system. The expansion in size of the individual issues has thus far been able to take care of the papers submitted. Ordinarily, the time interval between reception and appearance of the printed article has been from four to six months. In some instances a longer time is required, especially if the manuscript is returned to the author for revision. This average six months' interval does not seem unreasonable under present conditions, especially when compared with many other scientific publications, where the delay may be a year or even longer.

To the publishers should be accorded their full share of credit for continuing their high quality of workmanship and for maintaining a printing schedule that has assured delivery without undue delay.

Once again recognition and deep appreciation is here expressed for the generous and timely assistance received from The Geological Society in the form of financial support toward defraying a substantial portion of the ordinary publication costs and likewise for aid received when colored plates were deemed desirable.

In a detailed analysis of the Journal for 1948, we find that volume 33 contains 790 pages, exclusive of index. Leading articles, which number 55, occupy 77.6% of the total space. Table 1, which accompanies this report, indicates the distribution of the leading articles in the various fields listed. It might be of some interest to note that the average length of each of the main articles was slightly over 11 printed pages.

If to the 55 leading articles we add 18 shorter papers, appearing under the heading of Notes and News, we obtain a total of 73 published manuscripts for the calendar year.

* At a meeting of the Council held on Nov. 10, 1948, it was announced that a slight increase in dues for members and subscribers would be effective beginning Jan. 1, 1949.

These contributions were received from 85 contributors associated with 44 different universities, research bureaus, and technical laboratories. *

The Journal for 1948 carried a detailed description of one new mineral—mansfieldite. One hundred and ninety-five illustrations of various types assist in clarifying the descriptive portions of the text. Twelve contributions were received from contributors residing outside of the States, representing the following seven countries: Australia, Belgium, Brazil, Canada, England, Sweden, and Switzerland.

The accompanying Table 1 summarizes in detail the distribution of subject matter in volume 33.

TABLE 1. DISTRIBUTION OF SUBJECT MATTER IN VOLUME 33

<i>Subjects</i>	<i>Articles</i>	<i>Pages</i>	<i>Per Cent of Total</i>
Leading articles*			
Descriptive mineralogy.....	11		
Chemical mineralogy.....	16		
Structural crystallography.....	8		
Geometrical crystallography.....	2		
Petrography.....	2		
Optical mineralogy.....	8		
Mineralography.....	1		
Memorials	7		
Miscellaneous }			
	55	613	77.6
Shorter articles.....	18	42	22.4
Notes and news.....	43	12	
Proceedings of Societies.....	7	104	
Book reviews.....	10	9½	
New mineral names.....	28	9½	
Total entries.....	161	790	100.0
Illustrations.....	195		
Index, Title page, Table of contents.....		18	
Grand total.....		808	

Respectfully submitted,
WALTER F. HUNT, *Editor*

* Leading articles average 11.2 printed pages each.

REPORT OF THE TREASURER FOR THE FISCAL PERIOD BEGINNING DECEMBER 1, 1947, AND ENDING OCTOBER 31, 1948

To the Council of the Mineralogical Society of America:

Your treasurer submits herewith his report for the fiscal period beginning December 1, 1947, and ending October 31, 1948.

RECEIPTS

Cash on hand, December 1, 1947.....	\$ 1,752.17
Dues and subscriptions.....	4,290.95
Sale of back numbers.....	1,519.82
Authors' charges on separates.....	687.96
Interest and dividends from endowment.....	2,937.30
Payment on principal of Trenton Mortgage stock.....	405.32
Geological Society of America aid in printing the Journal.....	3,165.21
Advertising.....	143.30
Sale of 20-volume Index.....	5.00
Sale of Index to volumes 21-30.....	262.05
Sale of U. S. Treasury bond.....	5,251.56

\$20,420.64

DISBURSEMENTS

Printing and distribution of the Journal (5 issues).....	\$ 7,950.07
Printing and distribution of separates.....	872.61
To the Editor, Secretary, and Treasurer.....	1,208.34
Postage.....	357.08
Clerical and secretarial assistance.....	509.30
Office equipment.....	3.00
Printing and stationery.....	273.21
Safety deposit box.....	7.80
Telephone and telegraph.....	9.70
Committee expenses.....	3.55
Society luncheon.....	27.59
Roebbling Medal.....	139.40
Exchange charges on checks.....	2.14
Refund of dues.....	8.50
Travel expenses of officers to Annual Meeting.....	104.12
New securities purchased.....	5,997.67
Commission on new securities.....	3.13
Dividend adjustment on stock.....	7.75
Program and abstracts (1947).....	313.45
Duty on programs sent to Ottawa.....	9.00
Back numbers of the Journal purchased.....	34.00

\$17,841.41

Cash balance, October 31, 1948.....	2,579.23
-------------------------------------	----------

\$20,420.64

The endowment funds of the Society as of October 31, 1948, consist of the following securities:

BONDS

6M Atlantic Coast Line, 4½.....	\$ 5,257.50
5M Cleveland Union, Terminal, 5.....	5,068.75
5M Illinois Central, 4.....	3,887.50
5M New York Central, 5.....	4,300.00
5M Southern Railway, 5.....	5,743.75
4C Great Northern, 5½.....	400.00

PREFERRED STOCKS

200 shares, Southern California Edison, 4.88.....	\$ 5,250.00
100 shares, Union Pacific, 4.....	4,570.25
60 shares, Jones and Laughlin, A, 5.....	4,987.50
55 shares, U. S. Steel, 7.....	6,946.20
50 shares, Virginia Electric & Power Co., 5.....	5,942.50
24 shares, Public Service Electric & Gas Co.....	728.40
10 shares, Consolidated Edison.....	1,066.64
37 514/1000 shares, Trenton Mortgage Service.....	1,076.05*

COMMON STOCKS

50 shares, Chesapeake and Ohio Railway.....	\$ 2,368.75
50 shares, Pennsylvania Railroad.....	1,468.75
35 shares, American Telephone and Telegraph.....	4,819.32
26 shares, Standard Oil of New Jersey.....	1,390.72
1 share, New York, Chicago & St. Louis Railroad.....	37.00
	<hr/>
	\$65,309.58

* Residual value.

Respectfully submitted,
EARL INGERSON, *Treasurer*

DANA FUND

Disbursements are made to needy mineralogists in war areas and to needy families of deceased mineralogists in war areas.

RECEIPTS

Available balance, December 1, 1947.....	\$471.25
Interest.....	1.17
	<hr/>
	\$472.42

DISBURSEMENTS

Disbursed.....	\$100.00
Available balance, November 1, 1948.....	372.42
	<hr/>
	\$472.42

Respectfully submitted,
EARL INGERSON, *Treasurer*

REPORT OF THE AUDITING COMMITTEE

To the President of the Mineralogical Society of America:

The Auditing Committee has examined and verified the accounts of the Treasurer of the Mineralogical Society of America for the fiscal period ending October 31, 1948. The securities listed in the Treasurer's report, with all future coupons on the coupon bonds attached, are in the safety deposit box at the West End Branch of the Washington Loan and Trust Company in Washington, D. C.

Respectfully submitted,
JOHN F. SCHAIRER
GEORGE SWITZER
K. J. MURATA, *Chairman*

ABSTRACTS OF PAPERS PRESENTED AT THE TWENTY-NINTH ANNUAL MEETING OF THE MINERALOGICAL SOCIETY OF AMERICA, NEW YORK, N.Y., NOVEMBER 11-13, 1948

URANIUM MINERALS FROM THE HILLSIDE MINE, YAVAPAI COUNTY, ARIZONA

JOSEPH AXELROD, FRANK GRIMALDI, CHARLES MILTON, AND K. J. MURATA
U. S. Geological Survey, Washington, D. C.

A mineral assemblage, forming coatings on gypsum at the 300-foot level of the Hillside mine, contains a variety of hitherto unknown uranium minerals, together with schroeckeringerite, previously known only from Wyoming and Czechoslovakia. The new minerals are bayleyite, $\text{Mg}_2\text{UO}_2(\text{CO}_3)_3 \cdot n\text{H}_2\text{O}$, andersonite, $\text{Na}_2\text{CaUO}_2(\text{CO}_3)_3 \cdot n\text{H}_2\text{O}$, and swartzite, $\text{CaMgUO}_2(\text{CO}_3)_3 \cdot n\text{H}_2\text{O}$. There are also two other new unnamed substances which are dehydration products of bayleyite and swartzite. Bayleyite, swartzite and andersonite have been synthesized. Analyses, optical data and x-ray patterns of the new minerals are given together with x-ray patterns of the dehydration products. Schroeckeringerite has been analyzed and its formula found to differ from that given in the older accounts in the literature; our analysis agrees closely with that of the Wyoming schroeckeringerite recently reported by Jaffe, Sherwood and Peterson.

ELECTRON MICROSCOPY OF THE KAOLIN MINERALS

THOMAS F. BATES, FRED A. HILDEBRAND, AND ADA SWINEFORD
Pennsylvania State College, State College, Pennsylvania

The development of the electron microscope has made possible detailed morphological studies of the clay minerals.

Nacrite, dickite, and some kaolinites have been effectively studied with the petrographic microscope because of their relatively large, well-defined crystals. Endellite, halloysite, and allophane particles can only be observed in detail at magnifications greater than 5000 diameters.

Kaolinite crystals from different localities show appreciable variation in size but in only a few instances depart from the characteristic pseudo-hexagonal shape.

Endellite and halloysite crystals, previously described as "lath-shaped," are actually slender hollow tubes which show a considerable diversification in both shape and size in different specimens. The tubes are essentially cylindrical but in many cases are partially or completely flattened into ribbons. They are commonly split lengthwise and are often "unrolled" to a varying extent. Two, or occasionally more, concentric tubes are frequently observed.

Allophane particles are irregular in shape but similarity to some of the poorly crystallized halloysites suggests the possibility of a transition between these two minerals. Morphological evidence of the presence of intermediate members in a kaolinite-halloysite series is lacking.

Previous electron microscope work by the writer on the illite minerals (hydromicas) has shown that morphological differences bear a direct relation to the geological history of the rock in which they occur. The present work suggests that variations in the morphology of the kaolin minerals can be related to the mode of formation and subsequent history of the clay.

X-RAY MEASUREMENTS ON VAUQUELINITE

L. G. BERRY

Queen's University, Kingston, Ontario

New observations on vauquelinite crystals from Beresovsk, Urals, yield the following data: Monoclinic, $P2_1/n$. The unit cell, with $a=13.68$, $b=5.83$, $c=9.53$ Å, $\beta=93^\circ 58'$, $a:b:c=2.3465:1:1.6346$, contains $(Pb, Cu)_{12}[(Cr, P)O_4]_8$. Specific gravity 6.06 (measured, Dana), calculated 6.03 for $4[Pb_2Cu(CrO_4)(PO_4)]$. A well marked pseudo-cell with half the volume of the true cell and $2a'=[101]$, $b'=b$, $2c'=[\bar{1}01]$ has the same orientation and axial ratio as the morphological unit chosen by Goldschmidt.

REMAINS OF A GABBRO-GRANITE TRANSITION IN
NORFOLK COUNTY, MASSACHUSETTS

FELIX CHAYES

Geophysical Laboratory, Washington, D. C.

In a gradational transition specimens from the actual transition zone ought to be characteristically intermediate in composition. Compatibility with a "rectangular" or "equal frequency" parent distribution in the range of intermediate composition is suggested as a minimum criterion of gradation, and the statistical device of a one-sided chi-square test is proposed as a means of testing this compatibility.

The test is applied to a suite of specimens taken from a "gabbrodiorite"- "granodiorite" contact zone well exposed along route 128 in the townships of Dedham and Westwood, Norfolk Co., Mass.

These rocks are all extensively altered, but the alteration seems to have had little effect on the distribution of quartz. The quartz distribution is clearly incompatible with the proposed definition of gradation, rocks of intermediate quartz content being very scarce. It is concluded that this contact offers no evidence of an original gradation from gabbro to granite.

LITHIUM-BEARING PEGMATITES IN NORTHERN QUEBEC

DUNCAN R. DERRY

Toronto, Ontario

Lithium minerals, especially spodumene, are typical of many of the pegmatites occurring along the margins of a granitic stock in LaCorne Township, north of Val D'Or, Quebec. Recent diamond drilling has shown some interesting features in the structure and composition of these dikes.

The majority of the dikes strike nearly parallel to the nearest part of the granite contact and dip towards the centre of the stock. They occur both within the granite and just outside it in basic lavas or sediments.

The unusual feature of their composition is the uniformity in texture and average percentage of the spodumene in individual dikes. One series of such dikes on the north side of the stock shows an average spodumene content of about 25%. The crystals are arranged in a parallel pattern normal to the walls and are accompanied by feldspars, quartz, and minor amounts of beryl and tantalite. The texture of the more consistent dikes is finer than is usually seen in pegmatites. These finer-grained, uniform dikes are usually close to the granite contact while those closer to the centre of the stock are more variable in texture and spodumene content and contain more beryl.

No evidence has so far been seen that the present minerals were formed by replacement of earlier minerals in the dikes.

LIQUID INCLUSIONS IN HALITE AS A GUIDE TO GEOLOGIC THERMOMETRY

ROBERT M. DREYER, ROBERT M. GARRELS, ARTHUR L. HOWLAND
University of Kansas, Lawrence, Kansas; Northwestern University,
Evanston, Illinois

The gaseous phase of primary liquid inclusions in sedimentary Kansas halite vanishes between 70 and 100°C. This temperature probably is much above those temperatures generally prevailing in the Permian seas at the time of salt deposition. It is suggested that, if the liquid inclusion method is a valid guide to geologic thermometry, the method gives, after pertinent pressure corrections, only the temperature of the solution at the surface of the crystallizing material and that the general temperature of the mineralizing solutions may be much below that indicated by the liquid inclusions.

RETGERSITE, $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$, A NEW MINERAL

CLIFFORD FRONDEL AND CHARLES PALACHE
Harvard University, Cambridge, Massachusetts

The well-known artificial compound, tetragonal $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$, is described from five natural occurrences: with morenosite and minasragrite at Minasragra, Peru; with annabergite at Cottonwood Canyon, Churchill Co., Nevada, at Lobenstein, Thuringia, and at Lichtenberg, Bayreuth, Bavaria; and with ferroan chalcantite at the Gap Nickel Mine, Lancaster Co., Pennsylvania. Tetragonal trapezohedral, with $a:c=1:2.7038$ (artificial; Scacchi, 1863); $a_0=6.765$ kX, $c_0=18.20$, $a_0:c_0=1:2.690$ (Minasragra). Uniaxial negative, with $n_O=1.510$, $n_E=1.486$ (natural). Crystals from Minasragra are short prismatic $\{001\}$ with $\{001\}$, $\{110\}$, $\{011\}$, $\{012\}$; also found as fibrous crusts and veinlets. Color blue-green. G 2.04 (Nevada). Cleavage $\{001\}$ perfect, $\{110\}$ in traces. Analysis gave: NiO 26.87, MgO 0.65, FeO 0.63, SO_3 30.32, H_2O [41.53], total [100.00] (Nevada). The name retgersite is proposed for the mineral in honor of J. W. Retgers (1856–1896), Dutch chemical crystallographer.

Only four of the twenty-three reported natural occurrences of morenosite, orthorhombic $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$, can be said definitely to be of that species.

BASALTIC FAN JOINTING INDUCED BY AQUEOUS CHILLING

RICHARD E. FULLER
University of Washington, Seattle, Washington

At Rock Island, Washington, the eastern escarpment of the Columbia River Valley exposes a thick basaltic flow with marked "ball and socket" columnar jointing. Locally this flow shows the development of well defined columnar fan jointing radiating from vertical cracks which formed cooling surfaces. Laterally the fans grade rapidly from fine to coarse horizontal columns which have been confused with dikes. An alternation of smooth and rough transverse surfaces on the joint prisms of the fans as well as on the vertical columns of the flow also suggests exceptional acceleration of chilling. This chilling is considered to have been induced by the flooding of the surface of the flow with water, the presence of which is indicated by overlying palagonitic breccia formed by the aqueous granulation of a subsequent flow.

HYDROTHERMAL SYNTHESIS OF ENARGITE AND TENNANTITE

R. V. GAINES
Harvard University, Cambridge, Massachusetts

Crystallized enargite (Cu_3AsS_4) and tennantite ($\text{Cu}_{12}\text{As}_4\text{S}_{13}$) have been synthesized hydrothermally at temperatures in the range 350°–430°C. Arsenolite, orpiment, and several

unidentified substances were obtained in minor amounts in some instances concomitantly with enargite or tennantite. The reactants, which variously included Cu, CuCl, CuCl₂, CuS, As₂S₃, As₂O₅, S and Na₂S, together with water, were sealed in Vycor tubes and heated within steel pressure bombs of conventional design. The laboratory conditions favorable to the formation of enargite and tennantite were explored by variation of temperature, composition and pH of the solutions.

SOME ASPECTS OF THE SYSTEM $\text{NaAlSiO}_4\text{-CaO} \cdot \text{Al}_2\text{O}_3$

JULIAN R. GOLDSMITH

University of Chicago, Chicago, Illinois

The thermal-equilibrium relationships in the system $\text{NaAlSiO}_4\text{-CaO} \cdot \text{Al}_2\text{O}_3$ have been investigated. Complex relations exist at temperatures above the carnegieite-nepheline inversion range, the system at these temperatures being quaternary in nature. At lower temperatures, in the stability field of nepheline, simplification to a binary system is observed over a considerable portion of the system, due to the ability of nepheline to take up somewhat over 60 per cent $\text{CaO} \cdot \text{Al}_2\text{O}_3$ in solid solution. The complexity at higher temperatures is due to the inability of carnegieite to include more than a small amount of $\text{CaO} \cdot \text{Al}_2\text{O}_3$ in its structure, and to the intrusion of fields of $\beta\text{-Al}_2\text{O}_3$, corundum, and $\text{CaO} \cdot 2\text{Al}_2\text{O}_3$.

Soda volatilization is significant in the system, and apparently the rate is increased as lime is added. As soda is lost, $\beta\text{-Al}_2\text{O}_3$ or corundum tend to crystallize. The possibility of this effect being related to the corundum present in some alkaline rocks, particularly those associated with limestone, and to soda enrichment (albitization, etc.) of the country rock is discussed.

RETROGRESSIVE ALTERATION FOLLOWING GRANITIZATION AND RHEOMORPHISM

G. E. GOODSPEED

University of Washington, Seattle, Washington

At Cornucopia, Oregon, some areas of granitic rock are transected by numerous parallel alteration bands a few feet apart. They range from a fraction of an inch to 2 inches in width and have outer borders of sericitized and kaolinized granodiorite. Quartz is the chief mineral with some microcline and orthoclase. Were it not for the strong evidence that the granitic rock has been formed by metamorphism rather than consolidated from a magma, these bands would be interpreted as of deuteritic origin. The sericitization and kaolinization are indicative of temperature lower than that which obtained during granitization.

Rheomorphic dikes in this region exhibit crystalloblastic microtextures and pronounced flow structures. Some of these dikes, which are 4 or 5 feet wide and nearly vertical in attitude, are horizontally transected by light-colored alteration bands, up to 2 inches in width, several inches apart. These bands pinch out in the wall rock within 2 inches from the dike. They contain a few horizontal veinlets of epidote and chlorite. In a large thin section, it can be seen that the contacts with the unaltered part of the dikes are indistinct and that relict flow structure continues through them. Most of the original mafics of the dike have disappeared and even some of the plagioclase has been partially epidotized as well as kaolinized. There has been an apparent increase of alkali feldspar and quartz. It seems, therefore, that there is a close analogy in the mode of origin of these alteration bands to deuteritic processes in igneous rocks.

PRE-BELTIAN ROCKS NEAR DILLON, MONTANA*

E. WM. HEINRICH

University of Michigan, Ann Arbor, Michigan

Three major units of pre-Beltian metamorphic rocks occur near Dillon, Montana. The oldest consists of a series of banded gneisses that are similar to rocks of the Pony Series. Above these lies a group of marbles, schists, and quartzites, about two miles thick, belonging to the Cherry Creek Series. Hornblende gneiss, which is interlayered with these metasediments, represents chiefly metamorphosed mafic sills, for vestiges of earlier contact metamorphic effects are preserved and locally the gneisses transect the marbles. Cutting both Pony and Cherry Creek rocks is a batholith of red granite gneiss (Blacktail granite gneiss). Transecting these units are dikes and irregular sheets of pegmatite, diabase, and peridotite, unmetamorphosed and of uncertain age.

**THE MOORE COUNTY METEORITE; A FURTHER STUDY WITH COMMENT
ON ITS PRIMORDIAL ENVIRONMENT**

H. H. HESS AND E. P. HENDERSON

Princeton University, Princeton, New Jersey; U. S. National Museum,
Washington, D. C.

The Moore County meteorite in bulk composition resembles a Sudbury norite. The pyroxenes present were initially a single phase, pigeonite. This has undergone a complicated series of changes from which it is deduced that the temperature of the original environment was approximately 1135°C. and that the meteorite left this environment with catastrophic suddenness. Investigation of the fabric of the meteorite indicates a well-developed dimensional orientation of the plagioclase and pyroxene. The plagioclase *b* and *c* crystallographic axes and the pyroxene *c* axis tend to lie in one plane. The fabric is considered to represent primary layering developed by crystal accumulation on the floor of a magma chamber. This crystallization differentiation must have occurred in the original environment. Various lines of evidence suggest that the parent body from which the meteorite came was of the same order of magnitude of size as the Earth.

THE DISTRIBUTION OF ACCESSORY ELEMENTS IN PEGMATITES

H. D. HOLLAND AND J. L. KULP

Columbia University, New York

A mathematical theory for the distribution of accessory elements in the minerals of pegmatites is derived. The admittance of accessory elements by crystal lattices, the distribution of accessory elements as a function of the distance from the wallrock-pegmatite contact, and the effect of disturbing factors on the cooling history of a pegmatite are discussed. The theory is illustrated with an artificial example, and suggestions are made relative to its testing by experimental data. It is proposed that such testing will elucidate the mechanism of pegmatite formation.

ABSORPTION OF INFRA-RED RADIATION BY CLAY MINERALS

W. D. KELLER

University of Missouri, Columbia, Missouri

Absorption of infra-red radiation by clay minerals varies both in intensity and in wave lengths with the variety of clay mineral in the absorption chamber. Preliminary measurements suggest that certain clay minerals have characteristic infra-red absorption patterns, and that the absorption curves may be of help in the identification of clay minerals. Examples of absorption curves are shown.

* Published by permission of the Director, Montana Bureau of Mines and Geology.

THE PHYSICAL ANALYSIS OF POLYCOMPONENT GARNET

S. BENEDICT LEVIN

Signal Corps Engineering Laboratories, Fort Monmouth, New Jersey

The widespread occurrence and compositional variation of garnet, in relation to the character of the rock facies in which it is indigenous, make it a useful diagnostic mineral in many petrologic problems. This places a premium on methods for the relatively rapid and accurate determination of garnet composition, especially where many specimens or very small amounts of clean material are involved. For detailed compositional correlation the 3-component solutions afforded by the triangular diagrams of Ford and Winchell do not suffice, since most garnet specimens (probably over 85%) contain 4 or 5 of the theoretical component "molecules" in significant amounts, that is, one mol percent or more. Good 4-component solutions are afforded by the measurement of 3 physical properties which are independent (non-parallel) functions of the compositional variation, viz: index of refraction n , specific gravity G , and lattice constant a_0 . These values may readily be applied to an algebraic solution or to the tetrahedral graphical solution of Philipsborn, and (with the same data) will yield quantitative results considerably better than the geometric estimates of Stockwell.

For most occurrences, however, only a 5-component solution in terms of pyrope, almandite, spessartite, grossularite, and andradite, will account for 99% or more of each garnet specimen. Such solutions are afforded by supplementing the 3 physical measurements (n , G , a_0) with a rapid partial chemical analysis for either MnO or FeO. With these 4 measured quantities, and the summation to 100% providing the fifth, it is possible to set up and solve 5 simultaneous equations to yield the values of the 5 unknowns, i.e. the molecular proportions of the 5 component molecules. In connection with a recent study of Adirondack garnets, a general solution of the 5 simultaneous equations has been made and the algebraic calculations thereby abbreviated to about 20 minutes of machine calculating. In laboratories having the usual equipment, an x-ray diffraction camera, thermally calibrated high-index liquids, a micro-pycnometer, etc., this composite method results in considerable saving of time over wet chemical methods, especially where many analyses are needed. By measuring N to $\pm .001$, G to $\pm .005$, a_0 to $\pm .002$ Å, and MnO to $\pm .2\%$, results accurate to ± 1 mol per cent are obtained. Examples from the author's recent work are cited in illustration.

ARROJADITE AND GRAFTONITE FROM THE NICKEL PLATE MINE, SOUTH DAKOTA*

MARIE LOUISE LINDBERG

U. S. Geological Survey, Washington, D. C.

The iron phosphate described by Headden in 1891 from the Nickel Plate mine, South Dakota was reexamined. This material, not originally named, was later termed headdenite by Quensel and Mason, but is now known to be type unoxidized arrojadite. The massive sample appeared homogeneous, but a fresh interior surface showed graftonite, quartz, muscovite, and cassiterite. Thin sections show that the cassiterite occurs as subhedral grains or as thin seams containing rows of halos in the cleavage of the arrojadite. The analysis of arrojadite is: insoluble 0.11, Na₂O 6.40, K₂O 1.74, CaO 2.46, FeO 28.22, MnO 15.78; MgO 1.04, Li₂O 0.09, Al₂O₃ 2.66, Fe₂O₃ none, P₂O₅ 40.00, H₂O+0.91, F 0.80; total 100.21, less O=F₂ 0.34, total 99.87. Optical constants are: $\alpha=1.664$, $\beta=1.670$, $\gamma=1.675$, biaxial negative, $2V=86^\circ$, $r < v$ strong, X colorless, Y pale green, Z pale yellow green. The three strongest lines in the x-ray powder pattern are 3.04 Å, 2.715 Å, and 3.22 Å. The analysis of the graftonite is: insoluble 0.16, MnO 21.81, FeO 30.70, Fe₂O₃ none, Al₂O₃ 0.20, TiO₂ none, CaO 6.00, MgO 0.10, P₂O₅ 39.66, H₂O 0.60, Li₂O 0.05, Na₂O 0.28, K₂O none, F 0.20;

* Published by permission of the Director of the U. S. Geological Survey.

total 99.76, less O=0.08, total 99.68. The optical constants are $\alpha=1.713$, $\beta=1.719$, $\gamma=1.739$, biaxial+, $2V=60^\circ$, $r>v$ strong, X=Y=colorless, Z=pink. The three strongest lines are 3.96 Å, 3.21 Å, and 4.18 Å.

ANALCIME SUITE OF IGNEOUS ROCKS, BREWSTER COUNTY, TEXAS

JOHN T. LONSDALE AND KATHRYN K. O'NEILL

University of Texas, Austin, Texas

In southern Brewster County, Texas, a distinctive suite of alkalic rocks containing analcime is present in small laccoliths, sheets, sills, and dikes. The most abundant rock types are plagioclase-orthoclase (orthoclase, soda orthoclase, anorthoclase) rocks with aegirite, aegiritic pyroxene, olivine, apatite, analcime, and ore minerals. Biotite and hornblende are present in some specimens. Two masses contain nepheline rocks. These rocks have been called *analcime* basalt, nepheline basalt, trachybasalt, trachydolerite, syenogabbro, syenodiorite, and plagioclase syenite depending upon differences in texture and small but distinct mineralogical differences.

In many of the masses syenitic differentiates containing analcime, alkalic feldspar, aegiritic pyroxene, hornblende and biotite are present. Blebs, stringers, and small irregular bodies of syenite are common. In a few of the masses much larger bands and irregular masses are common. Some of these appear to be pegmatitic, others aplitic in character. The manner of occurrence and constant association of the differentiates preclude separate intrusions.

In all the rocks analcime formed late but is present in chilled borders of the larger masses as well as in the differentiates. There is evidence to indicate that it was nearly contemporaneous with alkalic feldspar, hornblende, and aegiritic pyroxene in the differentiates.

The complete suite shows a considerable range in composition and together with the mineral sequence suggests that the magmas were undergoing reaction when solidification occurred. The range of analyzed specimens is SiO₂, 40.17–61.28; Al₂O₃, 13.44–18.75; Fe₂O₃, 1.81–4.21; FeO, 1.53–9.72; MgO, 0.40–12.32; CaO, 1.24–12.55; Na₂O, 2.22–6.44; K₂O, 0.71–6.56; TiO₂, 0.67–3.51; P₂O₅, 0.11–1.04.

CHARTING FIVE AND SIX VARIABLES WITHIN THE BOUNDING TETRAHEDRA OF HYPERTETRAHEDRA

JOHN B. MERTIE, JR.*

U. S. Geological Survey, Washington, D. C.

Triangles, tetrahedra, and hypertetrahedra may be used as reference frames for charting variables whose sums equal unity. The number of variables that may theoretically be charted equals the number of vertices in the figure.

Hypertetrahedra of n dimensions are bounded by points, lines, triangles, tetrahedra, and hypertetrahedra of $n-1$ and fewer dimensions. Direct geometric charting within hypertetrahedra is impossible, as such figures can not be envisaged or constructed; but the variables may be plotted in groups within the bounding triangles of tetrahedra.

Methods have recently been presented by the writer for charting five, six, or seven variables in the bounding triangles of hypertetrahedra of four, five, and six dimensions. Methods are now given for charting five and six variables within the bounding tetrahedra of hypertetrahedra of four and five dimensions. For seven variables, these methods have little advantage over charting within the bounding triangles.

Analyses are arranged in all possible groups of four variables, and each group is recomputed to equal unity, or 100 per cent. These groups are plotted as points within the bounding tetrahedra; and each point is then projected orthogonally onto some selected tetra-

* Published by permission of the Director, U. S. Geological Survey.

hedral face. From an assemblage of such projected points, contour maps are made. Thus five variables are represented by five maps, and six variables are represented by fifteen maps.

Quadriplanar and trilinear coordinates are used. Negative coordinates and their uses are explained; and methods are given for amplification of scale when needed. For drawing contour maps, empirical arrangements of the tetrahedral faces of the bounding tetrahedra are presented.

THE ISOTHERMAL BOLYBARIC SATURATION CURVE AT 400° IN THE SYSTEM $\text{H}_2\text{O}-\text{Na}_2\text{O}-\text{SiO}_2$

GEORGE W. MOREY

Geophysical Laboratory, Washington, D. C.

The system $\text{H}_2\text{O}-\text{Na}_2\text{O} \cdot 2\text{SiO}_2$ can be treated as binary, and the lowering of melting point determined under increasing water pressure, only until about 600°. Then the solubility of Na_2O and in the vapor SiO_2 begin to be significant; and since the vapor contains more Na_2O than corresponds to the compound the system must be considered as ternary. Just below the critical end-point of water the solubility of $\text{Na}_2\text{O} \cdot 2\text{SiO}_2$ falls to practically zero, and the first critical end-point is practically at the critical point of water. The second critical end-point is a ternary one. Mixtures corresponding to the eutectic between sodium disilicate and water have a continuous solubility curve, so there must be a critical region bounded on both the high-silica and the high-soda sides. The isothermal polyboric solubility curve at 400° has been studied, with analyses of both vapor and liquid phases.

GEIKIELITE, A NEW FIND FROM CALIFORNIA*

JOSEPH MURDOCH AND J. J. FAHEY

University of California at Los Angeles, California, and
U. S. Geological Survey, Washington, D. C.

Geikielite, a magnesium titanate, has been found at the Jensen Quarry, Riverside County, California.

The mineral occurs in tiny grains and crystals sparingly disseminated through the crystalline brucite-limestone of the quarry, associated particularly with concentrations of minute grains of flesh-colored spinel.

In color it is deep red to nearly black, transparent red in thin crystals or fragments. Its specific gravity is 3.79.

Measurable crystals are rhombohedral, with the base dominant, one rhombohedron usually well developed, three others occasionally present. Forms, (0001), (10 $\bar{1}$ 1), (2025), (02 $\bar{2}$ 1), (01 $\bar{1}$ 2).

X-ray powder photographs, which can be completely indexed, confirm the structure to be C_{32} , with $c/a=2.67$, checking with the ilmenite group.

Composition was determined by chemical analysis of carefully purified material: TiO_2 64.9, Al_2O_3 1.3, MgO 31.8, FeO 1.4, MnO 0.4, SiO_2 0.9.

IGNEOUS ROCKS OF THE CAPITAN QUADRANGLE, NEW MEXICO

LEROY T. PATTON

Texas Technological College, Lubbock, Texas

Igneous rocks of the Capitan quadrangle, New Mexico, occur in the Capitan, Patos, Carrizo, Vera Cruz, and Sierra Blanca mountains, and in numerous small intrusions, dikes, sills and extrusive flows. The results of quantitative mineralogical analyses and the modes of the rocks are given.

* Published by permission of the Director, U. S. Geological Survey.

SCORZALITE FROM SOUTH DAKOTA: A NEW OCCURRENCE*

W. T. PECORA AND J. J. FAHEY

U. S. Geological Survey, Washington, D. C.

The mineral association, chemical analysis, and physical properties of scorzalite from a new occurrence are described. Analyzed material from the Victory pegmatite, near Custer, S. D., contains 17.06 per cent FeO, 2.93 per cent MgO, and has a Fe:Mg molecular ratio of 3:1. Scorzalite from this locality is the richest in iron of the known members of the lazulite-scorzalite isomorphous series.

HIGH POTASH VOLCANIC ROCKS, ST. FRANCOIS MOUNTAINS, MISSOURI†

FORBES ROBERTSON AND CARL TOLMAN

Montana School of Mines, Butte, Montana; Washington University, St. Louis, Missouri

The Pre-Cambrian of the St. Francois Mountains of Missouri is characterized by acidic igneous rocks including granites, intrusive porphyries and volcanics of various types. There are also some regionally distributed small gabbroic intrusions. The felsite flows are divided into two groups, both of which are characteristically high in potash feldspars. The feldspars of the younger group are characteristically perthitic. The feldspars of the older group and the rocks as a whole are high in potash and deficient in soda and lime. These rocks, especially the very high potash ones, are unique. The distribution, petrographic character, and chemical composition of these rocks are given.

THE SYSTEM K_2O -MgO-SiO₂

EDWIN W. ROEDDER

Columbia University, New York

The phase diagram of the more geologically significant portions of the condensed system has been determined by the quenching technique. Four new ternary compounds were found and their thermal relationships determined. Their compositions are $K_2O \cdot 5MgO \cdot 12SiO_2$, $K_2O \cdot MgO \cdot 5SiO_2$, $K_2O \cdot MgO \cdot 3SiO_2$, and $K_2O \cdot MgO \cdot SiO_2(?)$. The first of these may possibly occur naturally but has not been reported. The second and third appear to be isomorphous with leucite and kalsilite respectively, and the last is of comparatively little geologic interest. Composition and temperature have been determined for 23 of the invariant points occurring in the system. The geologic significance of the diagram in connection with the determination of the stability relationships of biotite is discussed, and a synthesis of phlogopite from a K_2O -MgO-Al₂O₃-SiO₂ glass at a temperature of 900°C. and 15,000 P.S.I. water pressure is reported. These studies were made at the Geophysical Laboratory during 1947-48 on a Carnegie Institution of Washington fellowship.

VARIATIONS IN DIFFERENTIAL THERMAL ANALYSIS CURVES OF SIDERITE

RICHARDS A. ROWLAND AND EDWARD C. JONAS

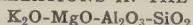
Houston, Texas

Differential thermal analysis curves of siderite obtained from samples minutely ground, diluted, variously packed, and combinations thereof are shown to frequently suppress the endothermic loop associated with the loss of CO₂. The effect of these variations on siderite DTA curves, which involve the loss of CO₂ followed by oxidation of FeO, is attributed, in part, to the diffusion of gas, both ways, through a packing and to differences in heat transfer.

* Published by permission of the Director, U. S. Geological Survey.

† Presented by permission of Edward L. Clark, State Geologist of Missouri.

PHASE EQUILIBRIUM RELATIONS IN THE QUATERNARY SYSTEM



J. F. SCHAIRER

Geophysical Laboratory, Washington, D. C.

Phase equilibrium studies are in progress or have recently been completed on six triangular joins within the quaternary system. Data are complete for the joins leucite—forsterite—silica, leucite—forsterite—potassium disilicate, and cordierite—forsterite—leucite; nearly complete for the joins leucite—clinoenstatite—potassium tetrasilicate and cordierite—leucite—silica; and in progress on the join cordierite—clinoenstatite—leucite.

Only one of these joins, leucite—forsterite—silica, is a ternary system within the quaternary system. This ternary system is, therefore, a composition plane which locates a temperature maximum in each quaternary univariant line which pierces this plane and thus effectively partitions the quaternary system. During crystallization of any type, no liquid can cross this composition barrier. This ternary system illustrates in a very striking manner the direction of change of composition in residual liquids from the fractional crystallization of a simplified magma. The femic constituents (in this case the olivine, forsterite and the pyroxene, clinoenstatite) are nearly completely removed first, leaving residual liquids that are potash-alumina-silicates. Appropriate compositions in the system, even though there is less than one half of one per cent forsterite in their total composition, crystallize the femic constituent clinoenstatite first and yield a residual liquid almost quantitatively free from the femic constituent.

The phase equilibrium data for the six joins are the first evidence bearing on the mutual stability relations of the rock-forming minerals—olivine, pyroxene, cordierite, leucite, potash feldspar, spinel, mullite, tridymite and cristobalite—in this quaternary system. There is evidence for solid solution in cordierites, and solid solution between leucite ($\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$) and $\text{K}_2\text{O} \cdot \text{MgO} \cdot 5\text{SiO}_2$ and between $\text{K}_2\text{O} \cdot \text{MgO} \cdot 3\text{SiO}_2$ and kalsilite ($\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$).

PETROLOGY OF VOLCANIC ROCKS OF NORTHEASTERN NEW MEXICO

HELEN STOBBE

Smith College, Northampton, Massachusetts

The igneous rocks described in this paper, were collected in an area about 86 by 50 miles in northern Union and eastern Colfax Counties, northeasternmost New Mexico. Lava-capped mesas and volcanic cones form prominent topographic features. The rocks are classified on a mineralogic basis. Basalts are the most widespread, dacites and andesites occur in subordinate amounts, and alkaline rocks as phonolites and soda trachytes are localized in about 24 square miles in central eastern Colfax County. Petrology substantiates three main periods of basaltic extrusion which physiography indicates; namely, Raton (earliest), Clayton (intermediate) and Capulin (recent). Olivine basalts predominate in all three periods and are mineralogically similar with textural variations. Raton basalts are the most uniform in texture and mineralogy. Clayton flows are predominately olivine basalts but include olivine basalts with quartz inclusions, analcime basanite, nepheline basalts, hauyne basalt and olivine-free basalts. Red Mountain dacites have built volcanic cones and occur as plugs and necks. The alkaline suite is sodic in character. Chico phonolites occur as flows chiefly; and Slagle trachytes associated with tinguaites and analcime microfoyaïtes occur in lesser amounts than the phonolites and are usually intrusives. The sodic rocks fall in line with the other alkaline groups which occur along the eastern front of the Rocky Mountains from British Columbia to Mexico. Dike rocks include leucocratic varieties as hornblende dacite, phonolite, tinguaites and analcime microfoyaïte; and melanocratic varieties as olivine basalt and lamprophyres (vogesite and monchiquite). The diverse rock types are believed to have originated from a parent olivine basalt magma.

THE ANALYSIS OF ROCK-FORMING MINERALS BY SPECTROCHEMICAL METHODS IN PETROLOGICAL RESEARCH

LESTER W. STROCK

Saratoga Laboratories, Inc., Saratoga Springs, New York

The possibility of using spectrochemical methods of analysis for determining the chemical compositions of rock-forming minerals in petrology has been examined, with a view of making both more unique and rapid characterizations of rocks than is at times possible by conventional petrographic methods. Such methods can at least provide data to supplement and check those obtained by optical crystallography; if not largely replace them.

Methods have been devised for determining the major and important minor constituents in garnets and ferromagnesian minerals. Work on micas and feldspars is in progress and will be reported later. The methods are applicable for analyzing rocks and minerals separated from the rocks. Samples weighing as little as 1 mg. may be accurately analyzed which makes it possible to study individual mineral grains and fragments of zoned crystals. Actual mineral samples of accurately known chemical analysis were used as standards. In addition to the major constituents, minor elements, such as Cr, Ti, V, etc., which are known to influence certain optical properties, can be determined simultaneously. One limitation is the necessity of determining only total iron.

ARTIFICIAL QUARTZ BY HYDROTHERMAL METHODS

A. C. SWINNERTON

Antioch College, Yellow Springs, Ohio.

Quartz has been grown by several investigators but obtaining continuous growth to produce large single crystals is a special problem. The present investigation, sponsored by the U. S. Army Signal Corps, has canvassed systematically the growth fields for a range of concentrations of NaCl, NaCl with alkalinity adjusted with NaOH, at 400°C, with and without temperature gradient, in the range of 3000 to 6000 psi, using fused silica as source material and AT-cut plates (crystalline) as seeds. The results are presented, the effect of the critical temperature is discussed and suggestions are made regarding the chemical reactions involved.

THE VARIABLE INVERSION TEMPERATURE OF QUARTZ AS A POSSIBLE GEOLOGIC THERMOMETER

O. F. TUTTLE

Geophysical Laboratory, Washington, D. C.

The inversion temperature of quartz has been found to vary as much as 1.89°C. All quartz specimens so far investigated from high temperature sources (e.g., phenocrysts in lavas) invert at a lower temperature than quartz from low temperature deposits (e.g., grown in vugs in limestone). The variation is believed to be due to solid solution, probably predominantly of the interstitial type. The high temperature modification has a more open structure, permitting a greater amount of solid solution with consequent lowering of the inversion temperature.

WHAT IS A MINERAL?

ALEXANDER N. WINCHELL

Hamden, Connecticut

The old definition of a mineral as a natural inorganic substance of definite chemical composition is criticized, a new definition is proposed, and its effects are illustrated.

THERMAL STUDY OF RHODOCHROSITE

HAROLD D. WRIGHT, J. LAURENCE KULP, AND RALPH J. HOLMES
Columbia University, New York

Representative specimens of rhodochrosite from many localities have been examined by the method of differential thermal analysis in order to establish the form and variations of the thermal curve of the mineral, and to study the effect of cation substitution on its thermal behavior. The optimum conditions of sample and apparatus providing reproducible thermal curves for this mineral group are discussed.

The endothermic peak was found to reproduce more consistently than the exothermic, varying from 609°C. to 724°C. but only one specimen gave an endothermic peak higher than 667°C. The majority range from 609°C. to 635°C. The temperature at which the endothermic peak occurs is raised by the presence of Ca and Mg and is lowered if iron substitutes for manganese in the lattice.

The materials used in the thermal work were checked by means of x-ray powder patterns and semi-quantitative tests for the cations in question.

Several specimens of manganocalcite varying widely in manganese content indicate that the substitution of Mn for Ca in the series calcite-rhodochrosite is probably continuous and unlimited.

ACTIVITY MEASUREMENTS OF MICRO-RADIOACTIVE INCLUSIONS

HERMAN YAGODA
National Institute of Health, Bethesda, Maryland

The activity of minute radioactive segregates in polished sections of rocks or micro-incinerated biological tissue is determined by counting alpha particle tracks recorded in nuclear type emulsions. Precise localization of particular segregates whose area exceeds 10^{-4} cm² is established by a double-exposure technique. The track count affords, in certain instances, an approximate measure of either the U or Th content. Applications of the method in the study of segregates in feldspar, beryl, and other minerals associated with radioactive ores will be described.

LIST OF FORMER OFFICERS AND MEETING PLACES

By recommendation of the Council, a complete list of past officers is printed in the proceedings of the annual meeting of the Society:

PRESIDENTS	VICE-PRESIDENTS
1920 Edward H. Kraus	Thomas L. Walker
1921 Charles Palache	Waldemar T. Schaller
1922 Thomas L. Walker	Frederick A. Canfield
1923 Edgar T. Wherry	George F. Kunz
1924 Henry S. Washington	Washington A. Roebling
1925 Arthur S. Eakle	Herbert P. Whitlock
1926 Waldemar T. Schaller	George Vaux, Jr.
1927 Austin F. Rogers	George L. English
1928 Esper S. Larsen	Lazard Cahn
1929 Arthur L. Parsons	Edward Wigglesworth
1930 Herbert E. Merwin	John E. Wolff
1931 Alexander H. Phillips	William F. Foshag
1932 Alexander N. Winchell	Joseph L. Gillson
1933 Herbert P. Whitlock	Frank N. Guild
1934 John E. Wolff	William A. Tarr
1935 Clarence S. Ross	Ellis Thomson
1936 William S. Bayley	Harold L. Alling
1937 Norman L. Bowen	H. V. Ellsworth
1938 Ellis Thomson	Kenneth K. Landes
1939 Max N. Short	Burnham S. Colburn
1940 William F. Foshag	Ian Campbell
1941 Frederick E. Wright	William J. McCaughey
1942 Arthur F. Buddington	Martin J. Buerger
1943 John F. Schairer	John W. Gruner
1944 R. C. Emmons	Harry Berman
1945 Kenneth K. Landes	George Tunell
1946 Paul F. Kerr	S. B. Hendricks
1947 M. J. Buerger	Carl Tolman
1948 M. A. Peacock	Adolf Pabst
SECRETARIES	TREASURERS
1920-1922 Herbert P. Whitlock	1920-1923 Albert B. Peck
1923-1933 Frank R. Van Horn	1924-1929 Alexander H. Phillips
1933-1934 Albert B. Peck	1929-1930 Albert B. Peck
1934-1944 Paul F. Kerr	1931-1940 Waldemar T. Schaller
1944- C. S. Hurlbut, Jr.	1941- Earl Ingerson

EDITORS

1920-1921 Edgar T. Wherry
1922- Walter F. Hunt

COUNCILORS

1920 Arthur S. Eakle, Frank R. Van Horn, Fred E. Wright, Alexander H. Phillips.
1921 Frank R. Van Horn, Fred E. Wright, Alexander H. Phillips, Austin F. Rogers.
1922 Fred E. Wright, Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson.

- 1923 Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson, Esper S. Larsen.
- 1924 Austin F. Rogers, Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons.
- 1925 Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons, William F. Foshag.
- 1926 Esper S. Larsen, Arthur L. Parsons, William F. Foshag, William A. Tarr.
- 1927 Arthur L. Parsons, William F. Foshag, William A. Tarr, Alexander N. Winchell.
- 1928 William F. Foshag, William A. Tarr, Alexander N. Winchell, Ellis Thomson.
- 1929 William A. Tarr, Alexander N. Winchell, Ellis Thomson, Clarence S. Ross.
- 1930 Alexander N. Winchell, Ellis Thomson, Clarence S. Ross, Paul F. Kerr.
- 1931 Ellis Thomson, Clarence S. Ross, Paul F. Kerr, William S. Bayley.
- 1932 Clarence S. Ross, Paul F. Kerr, William S. Bayley, William J. McCaughey.
- 1933 Paul F. Kerr, William S. Bayley, William J. McCaughey, Kenneth K. Landes.
- 1934 Arthur S. Bayley, William J. McCaughey, Kenneth K. Landes, E. P. Henderson.
- 1935 William J. McCaughey, Kenneth K. Landes, E. P. Henderson, J. F. Schairer.
- 1936 Kenneth K. Landes, E. P. Henderson, J. F. Schairer, Arthur F. Buddington.
- 1937 E. P. Henderson, J. F. Schairer, Arthur F. Buddington, Arthur P. Honess.
- 1938 J. F. Schairer, Arthur F. Buddington, Arthur P. Honess, R. C. Emmons.
- 1939 Arthur F. Buddington, Arthur P. Honess, R. C. Emmons, Carl Tolman.
- 1940 Arthur P. Honess, R. C. Emmons, Carl Tolman, D. Jerome Fisher.
- 1941 R. C. Emmons, Carl Tolman, D. Jerome Fisher, Martin A. Peacock.
- 1942 Carl Tolman, D. Jerome Fisher, Martin A. Peacock, Adolf Pabst.
- 1943 D. Jerome Fisher, Martin A. Peacock, Adolf Pabst, C. S. Hurlbut, Jr.
- 1944 Martin A. Peacock, Adolf Pabst, Michael Fleischer, S. J. Shand.
- 1945 Adolf Pabst, Michael Fleischer, S. J. Shand, R. E. Grim.
- 1946 Michael Fleischer, S. J. Shand, R. E. Grim, Joseph Murdoch.
- 1947 S. J. Shand, R. E. Grim, Joseph Murdoch, H. H. Hess.
- 1948 R. E. Grim, Joseph Murdoch, H. H. Hess, Clifford Frondel.

ANNUAL MEETING PLACES

- | | |
|-------------------------------|-------------------------------|
| 1920 Chicago, Illinois | 1934 Rochester, New York |
| 1921 Amherst, Massachusetts | 1935 New York, N. Y. |
| 1922 Ann Arbor, Michigan | 1936 Cincinnati, Ohio |
| 1923 Washington, D. C. | 1937 Washington, D. C. |
| 1924 Ithaca, New York | 1938 New York, N. Y. |
| 1925 New Haven, Connecticut | 1939 Minneapolis, Minnesota |
| 1926 Madison, Wisconsin | 1940 Austin, Texas |
| 1927 Cleveland, Ohio | 1941 Boston, Massachusetts |
| 1928 New York, N. Y. | 1942 No meeting held |
| 1929 Washington, D. C. | 1943 No meeting held |
| 1930 Toronto, Canada | 1944 No meeting held |
| 1931 Tulsa, Oklahoma | 1945 Pittsburgh, Pennsylvania |
| 1932 Cambridge, Massachusetts | 1946 Chicago, Illinois |
| 1933 Chicago, Illinois | 1947 Ottawa, Canada |
| | 1948 New York, N. Y. |

RECIPIENTS OF THE ROEBLING MEDAL

- | | |
|--------------------------------------|---------------------------------------|
| Charles Palache, December 1937 | Edward H. Kraus, February 1945 |
| Waldemar T. Schaller, December 1938 | Clarence S. Ross, December 1946 |
| Leonard James Spencer, December 1940 | Paul Niggli, December 1947 |
| Esper S. Larsen, Jr., December 1941 | William Lawrence Bragg, November 1948 |

CONFERENCE ON THE TEACHING OF CRYSTALLOGRAPHY*

The following five speakers took part in the Conference covering different phases of the teaching of crystallography: J. D. H. Donnay, D. Jerome Fisher, Samuel G. Gordon, M. A. Peacock, and George Tunell. Brief abstracts of the papers follow.

FROM THE LAW OF RATIONALITY TO THE LAW OF BRAVAIS

J. D. H. DONNAY, *The Johns Hopkins University, Baltimore, Maryland.*

The Law of Rationality is best introduced in a form that lends itself to direct experimental check—expressed in terms of *direction angles* of face normals (rather than *intercepts* of faces), since such angles are either measured on the goniometer or calculated from measured angles. Take coordinate axes Ox , Oy , Oz , parallel to the three (non-coplanar) edges between three suitable faces. Consider a fourth face, intersecting all three axes, and let ξ , η , ζ be the angles which its normal makes with the axes Ox , Oy , Oz , respectively. Let ξ' , η' , ζ' be the direction angles of the normal to any fifth face. The law of observation says: "quotients of corresponding direction cosines are in the ratios of small integers", or

$$\frac{\cos \xi}{\cos \xi'} : \frac{\cos \eta}{\cos \eta'} : \frac{\cos \zeta}{\cos \zeta'} = h:k:l, \quad (1)$$

where h , k , l , small integers, are the *Miller indices* of the fifth face. From (1) it appears that the indices of the fourth face are (111), hence its name "unit face."

Since the intercepts of a plane and the direction cosines of its normal are inversely proportional (a theorem easy to prove), (1) can be written as

$$a \cos \xi : b \cos \eta : c \cos \zeta = h:k:l, \quad (2)$$

where a , b , c , the unit lengths, are the intercepts of any plane parallel to the unit face. This is the "fundamental formula," the key to all crystallographic calculations, used to determine both *axial ratios* and *face indices*.

Likewise (2) becomes

$$\frac{a}{OH} : \frac{b}{OK} : \frac{c}{OL} = h:k:l,$$

where OH , OK , OL are the intercepts of any plane parallel to the fifth face. This is immediately rewritten in the familiar form

$$OH:OK:OL = \frac{a}{h} : \frac{b}{k} : \frac{c}{l} \quad (3)$$

or, reducing to the common denominator and clearing common factors, as

$$OH:OK:OL = kl a : lk b : hk c = ea : fb : gc, \quad (4)$$

where e , f , g , small integers, are the *Weiss coefficients* of the fifth face. In ordinary language, "any fifth face is parallel to a plane whose intercepts are either simple fractions (relation 3) or small multiples (relation 4) of the unit lengths."

Construct a lattice on a , b , c , taken as primitive translations. Let $OH=ea$, $OK=fb$, $OL=gc$. We see from (4) that the fifth face is parallel to a plane HKL passing through

* Brief abstracts of papers presented at the Conference on the Teaching of Crystallography, 29th Annual Meeting of The Mineralogical Society of America, New York, November 12, 1948.

three nodes, that is to say, a net plane. Moreover, since e, f, g are small, triangle HKL is small (in terms of unit lengths), and a parallelogram HKLM, whose area is twice that of triangle HKL, is also small. Points H, K, L, M, are lattice nodes, and parallelogram HKLM is either the smallest mesh or a multiple mesh of the net HKL; the smallest mesh, in either case, is thus small. Hence, the Law of Rationality can be stated in reticular terms: "any face is parallel to a net with small mesh area" or, since mesh area and interplanar distance are inversely proportional, "any face is parallel to a stratification of nets with large interplanar distance."

The Classical Law of Bravais naturally follows as an additional law of observation: "usually the faces actually observed are parallel to nets with largest interplanar distances; the larger the interplanar distance, the more frequent (and the larger) the face." (The Generalized Law cannot be introduced at this point, of course, since it requires some knowledge of space-group symmetry.)

CHANGES IN THE OBJECTIVES IN THE TEACHING OF MINERALOGICAL CRYSTALLOGRAPHY

D. JEROME FISHER, *University of Chicago.*

An attempt is made to outline a beginning course covering the basic crystallography needed by the modern mineralogist. Assumed prerequisites are one year's college work of good calibre in each of the following subjects mathematics, physics, and chemistry. The total time required by the average well-prepared student is taken as 175 hours, subdivided as shown in Table 1.

TABLE 1. A BASIC COURSE IN MINERALOGICAL CRYSTALLOGRAPHY

Subject	Time in hours				Per Cent of total time
	Class ¹	Super-vised labora-tory	Re-mainder ²	Total	
Morphology	6	6	18	30	17
Crystal Physics ³	21	21	63	105	60
Fracture ⁴	1	1	3	5	3
Isotropics	5	5	15	25	14
Uniaxials	8	8	24	40	23
Biaxials	7	7	21	35	20
Crystal Chemistry	7	3	25	35	20
X-ray diffraction ⁵	3	3	9	15	8½
Chemical crystallography	4	—	16	20	11½
Final examination	3	2	—	5	3
Total	37	32	106	175	100

¹ Lecture, discussion, quiz and examination.

² Unsupervised laboratory, problems, reading; *total* time assumed for the course is 175 hours.

³ Microscopical crystallography in the main.

⁴ Including cleavage, parting, gliding.

⁵ Some might prefer to class this under crystal physics.

There is no single text-book in English which covers this ground with the distribution of space to the various topics like that here called for; see Table 2. The major objective of the course is the theory and practice of the determination of the optical constants of crushed grains in oils with the aid of the polarizing microscope.

TABLE 2. SUBDIVISIONS OF SPACE IN MINERALOGY TEXTS

Text	Subject						Total	
	Morphology		Crystal Physics		Crystal Chemistry ¹			
	Pp.	%	Pp.	%	Pp.	%	Pp.	%
Dana-Hurlbut	65	85	2	3	7	9	74	97
Kraus <i>et al.</i>	88	59	31	21	24	17	143	97
Rogers	108	55	55	28	27	14	190	97
Winchell	112	69	34	21	12	7	158	97
Dana-Ford	168	54	107	35	26	8	301	97
Bunn ²	46	21	57	26	110	50	213	97
Average ³	108	61	46	26	19	10	173	97
D.J.F. (time)	—	17	—	60	—	20	—	97

¹ Including X-ray diffraction.

² Bunn, C. W., Chemical Crystallography, 1945. This is not a mineralogical text. It is relatively weak on crystal chemistry, though strong on x-ray diffraction. Chapters 7, 9, 10, and 11 are not counted in the above table.

³ Excluding Bunn.

Some idea of the level of instruction may be judged from the final examination. This is in two parts, theory and practice. Following is a current theoretical examination (two hours).

N.B.—Notes and books may be used *except* do not look up the properties of sulfur asked for in any book. Give reasoning and show work for all answers.

Given a crystal of sulfur for which face (221) has $\phi = 50^\circ 53'$ and $\rho = 80^\circ 35\frac{1}{2}'$. $a_0 = 10.48 \text{ \AA}$. Indices of refraction are 1.96, 2.04, 2.25 with $2V$ of 69° . Optic plane is (010) and $a = \alpha$. Density is 2.07. Assume cleavage parallel (105).

(1) Crystal System

(2) Optic Sign

(3) Axial ratio

(4) (a) "Picture" of interference figure 45° from extinction when lying on cleavage face (12.4 microns thick).

(b) Show how isochromes will move if a quartz wedge (Z lengthwise) is inserted from the SE.

(5) Extinction angle (and sign) when lying on (221).

(6) (a) Number of atoms in unit cell.

(b) Percentage "porosity."

(c) What can you say of the type of packing?

THE ROLE OF THE MUSEUM IN THE TEACHING OF CRYSTALLOGRAPHY

SAMUEL G. GORDON, *The Academy of Natural Sciences of Philadelphia.*

A distinction is made between a public museum, and a museum in a university, where it can be a useful adjunct in the teaching of crystallography. A museum exhibit must be graded to the experience level of the visitor, and a successful visual demonstration must be designed primarily for that purpose. An example is the "What is a Crystal?" exhibit in the mineral gallery of the Academy of Natural Sciences of Philadelphia. As any mineral collection is essentially an exhibit of crystals, these should be made more understandable to the visitor by the use of structure models, particularly those which will serve as a key to the classification of the minerals.

Exhibits should show the fundamental significance of crystallography to the petrographer and geologist, for much of what is called geochemistry could better be designated as geocrystallography. A mineral may be defined as a naturally occurring symmetrical structural arrangement of atoms, whose chemical composition can be expressed by an empirical formula to define a species. Mineralogy would then be defined as the study of these naturally occurring arrangements of atoms, their internal pattern and external forms; the origin of the structures; their physical and chemical properties; occurrence; and the effect upon them of physical forces and wandering ions.

THE TEACHING OF MORPHOLOGICAL CRYSTALLOGRAPHY

M. A. PEACOCK, *University of Toronto, Toronto, Canada.*

Morphological crystallography—the theory underlying the description of crystal form—may be taught as an independent subject; but then it is essentially a branch of mathematics and the interest is apt to lie in mathematical elegance rather than in the forms of actual crystals, which the student may see only as represented by models and drawings. Conversely, practical crystallography can be undertaken with a minimum preparation in crystal geometry; but then the work tends to become a handicraft in which the whole interest is in the faithful description of the forms of crystals by measurements, drawings, and calculations, and little thought is given to the central problem of crystal form, namely the relation of form to other crystal properties, particularly the internal structure. Concurrent or consecutive work in theory and practice will counter these tendencies, giving the student a sound grasp of classical crystallography and a good preparation for the study of crystal structure.¹

A course in morphological crystallography may commence with a consideration of the crystal lattice—the triperiodic array of structurally identical points in a crystal—which was firmly inferred from the Laws of Constant Angles and Simple Rational Intercepts and later demonstrated by the diffraction of x -rays. Accepting crystal faces as limiting lattice planes, the whole metrical aspect of crystal morphology can be developed from the crystal lattice and the auxiliary conception of the reciprocal lattice. The fourteen lattice types and the six metrical groups (provisional crystal systems) with their characteristic types of elements (axial ratios) may first be derived; the notation for crystal faces and edges is easily explained and, with the necessary geometry and trigonometry, their representation in stereographic and gnomonic projections is conveniently dealt with; and the derivation of cell elements from single-circle and two-circle measurements, and the converse calcula-

¹ In the course in Mineralogy in the University of Toronto morphological crystallography, crystal measurement, and x -ray crystallography are prescribed in the second, third, and fourth undergraduate years, respectively.

tion of angles from established elements, can be treated in this sequence. Importance should be attached to the choice of the crystal lattice from angular measurements; this should, but for the rarest exceptions, correspond to the structural lattice as determined by x -rays. It is instructive to make this choice on morphological grounds without reference to the röntgenographic findings; and for this purpose the Bravais principle, especially as generalized by Donnay, and its gnomonic expression in the Harmonic-Arithmetic Rule, are effective and reliable aids.

The foregoing work can be developed with little reference to crystal symmetry, which can now be studied in a systematic manner, preferably with the use of the Hermann-Mauguin notation which requires rotation and rotation-inversion rather than rotation-reflection. Anticipating the needs of structural crystallography the thirty-two crystal classes should be rigorously deduced and grouped in the Laue Symmetries, and the possibilities of electrical polarity and optical activity in each class should be mentioned. At this point it would be well to redefine the crystal systems on the basis of symmetry, as seven rather than six groups of classes, in which any lattice element may fortuitously take special values which are incompatible with the provisional metrical definitions of crystal systems. The principles on which the space-groups are built can now be explained and the striking influence of glide-planes and screw-axes on crystal morphology, discovered by Donnay and Harker, can be illustrated. And finally the common occurrence of metrical pseudo-symmetry in crystals and its intimate relation to crystal twinning, so beautifully developed by Friedel, deserves more than passing mention.

This theoretical work always proceeds from the general to the special—the triclinic to the cubic—and consequently the practical work would logically follow the same course. Although contrary to current practice it might prove quite feasible to commence with a triclinic crystal and learn the full complexities at the outset. Exercises in the higher symmetries could then be carried through rapidly as relatively easy special cases.

THE TEACHING OF X-RAY CRYSTALLOGRAPHY

GEORGE TUNELL, *University of California, Los Angeles, California.*

Present day students of mineralogy need to learn the use of the x -ray powder diffraction method on account of its great utility and ease of application in the identification of crystalline substances. One lecture and one laboratory exercise in the beginning mineralogy course should suffice for this purpose. Students of elementary mineralogy also need at least an introduction to the structures of some of the commoner minerals in order to gain an insight into their chemical constitution and such physical properties as cleavage and refractive index.

Most students intending to specialize in mineralogy will wish to learn the methods of determining unit cell dimensions (edge lengths and inter-edge angles) by the diffraction of essentially monochromatic x -rays by single crystals. The equation existing between the unit cell volume, the density, and the chemical composition is an important aid to the mineralogist in checking these data, and its application is worthy of emphasis.

Those students of mineralogy especially interested in crystallography will go on to learn the detailed methods of determining the atomic arrangements in crystals by the analyses of the intensities of x -ray beams diffracted by single crystals and by powder specimens. These methods involve the use of Fourier series to calculate the distributions of electron densities in the unit cells as well as the use of the results of the theory of space groups. The study of atomic arrangements is beginning to provide a new quantitative picture of chemical bonds as well as of some of the important physical properties. An advanced course devoted to these topics will naturally include laboratory exercises with x -ray equipment, the optical goniometer, and the petrographic microscope.

CORRESPONDENTS, FELLOWS, MEMBERS AND SUBSCRIBERS OF THE MINERALOGICAL SOCIETY OF AMERICA†

CORRESPONDENTS

- ESKOLA, PENTTI, Geological Institute of the University, Snellmaninkatu 5, Helsinki, Finland.
- NIGGLI, PAUL, Eidg. Technische Hochschule, Min.-Petro. Institut, Sonneggstrasse 5, Zürich, Switzerland.
- SLAVÍK, FRANTISEK, Albertov 6, Praha, Czechoslovakia.
- SPENCER, L. J., 111 Albert Bridge Road, London, S.W. 11, England.
- TILLEY, C. E., Cambridge University, Cambridge, England.

FELLOWS AND MEMBERS

(*Indicates Fellow)

- ABBOTT, JOHN L., 5540 N. Shoreland Avenue, Milwaukee 11, Wisconsin.
- *ADAMS, ELLIOT Q., Lamp Development Laboratory, Nela Park, Cleveland, Ohio.
- ADAMS, JOHN WAGSTAFF, U. S. Geological Survey, Washington 25, D. C.
- *AGAR, WILLIAM M., 182 East End Avenue, New York 28, N. Y.
- AGHION, HENRI, 26, Rue Chérif Pacha, Alexandrie, Le.-Egypte.
- AGRELL, S. O., Dept. of Geology, University of Manchester, Manchester 13, England.
- *AHLFELD, FEDERICO, Casilla 582, Cochabamba, Bolivia.
- ALBRECHT, HERBERT O., 62 S. Hillcrest Road, Springfield, Pennsylvania.
- *ALDRICH, HENRY R., 419 West 117th Street, New York 27, N. Y.
- ALEXANDER, A. E., 155 East 47th Street, New York, N. Y.
- ALF, RAYMOND M., Webb School, Claremont, California.
- ALLEN, ALFRED W., Dept. of Ceramic Engineering, University of Illinois, Urbana, Illinois.
- ALLEN, C. M., Bay House, Pembroke, Bermuda.
- *ALLEN, VICTOR T., Institute of Geophysical Technology, 3621 Olive Street, St. Louis 8, Missouri.
- ALLEN, WILLIAM T., 318 56th Street, Newport News, Virginia.
- *ALLING, HAROLD L., 901 East Avenue, Rochester 7, New York.
- ANDERSON, A. BENTON, Hazardville, Connecticut.
- *ANDERSON, ALFRED LEONARD, Department of Geology, Cornell University, Ithaca, New York.
- *ANDERSON, CHARLES A., Box 633, Prescott, Arizona.
- *ANDERSON, GEORGE H., Vice-President, Lone Star Steel Co., 215 Cotton Exchange Bldg., Dallas 1, Texas.
- ANDERSON, J. L., Department of Geology, Johns Hopkins University, Baltimore 18, Maryland.
- ANDERSON, RICHARD J., Battelle Memorial Institute, Columbus 1, Ohio.
- ANDREATTA, CIRO, Istituto di Mineralogia e Petrografia, Università di Bologna, Via Zamboni 94, Bologna, Italia.
- ANDREW, GERALD, Box 410, Geological Survey, Khartum, Anglo-Egyptian Sudan.
- ANDREWS, T. G., Main Library, University of Alabama, University, Alabama.
- ANTHONY, JOHN W., Arizona Bureau of Mines, University of Arizona, Tucson, Arizona.
- ARELLANO, A. R. V., Sr., Apartado 8393, Mexico, D. F., Mexico.
- ARMINSTROUT, PAUL, Allegan, Michigan.

† Changes received by the Secretary since January 10, 1949, are not included.

- ARMISTEAD, DONALD A., 5 Grove Avenue, Auburn, New York.
- ARNEY, TOM, 110 West 2nd Street, Newberg, Oregon.
- ARSCHINOW, W. W., Bol. Ordinka, 32, kw. 1, Moscow, U.S.S.R.
- ASGIAN, CHARLES, Party 36, Western Geophysical Company, Cody, Wyoming.
- *ASHCROFT, FREDERICK N., 38 Melbury Court, Kensington, London, W. 8, England.
- AXELROD, JOSEPH, U. S. Geological Survey, Washington 25, D. C.
- AYCARDO, MAN M., JR., North Camarines Gold Mining Co., Paracale, Camarines Norte, Philippine Islands.
- BACON, CHARLES S., JR., Dept. of Geology and Mineralogy, Case Institute of Technology, Cleveland 6, Ohio.
- BAGROWSKI, B. P., 1722 South 22nd Street, Milwaukee 4, Wisconsin.
- BAHR, BILL, 550 Cedar Street, Winnetka, Illinois.
- BAILEY, EDGAR H., c/o U. S. Geological Survey, Box 208, Los Gatos, California.
- BAILEY, RENE, Dept. of Geology, Washington University, St. Louis 5, Missouri.
- BAILEY, S. W., Dept. of Geology, University of Wisconsin, Madison, Wisconsin.
- *BAIN, GEORGE W., 12 Dana Street, Amherst, Massachusetts.
- BAIRD, IAN F., P.O. Box 385, Hamilton, New Zealand.
- BALES, C. E., Ironton Firebrick Co., Ironton, Ohio.
- BALKE, CLAIRE C., 501 Lombardy Road, Drexel Hill, Pennsylvania.
- *BANDY, MARK C., Redfield, Iowa.
- BANK, WALTER, U. S. Bureau of Mines, 4800 Forbes Street, Pittsburgh 13, Pennsylvania.
- *BANNERMAN, HAROLD M., U. S. Geological Survey, Washington 25, D. C.
- *BANNISTER, F. A., 34 Monahan Avenue, Purley, Surrey, England.
- BARCLAY, GEORGE C., P.O. Box 433, Newport News, Virginia.
- BARKOW, ARTHUR G., Physics Department, Marquette University, Milwaukee 3, Wisconsin.
- *BARKSDALE, JULIAN DEVEREAU, Dept. of Geology, University of Washington, Seattle 5, Washington.
- *BARNES, VIRGIL E., 207 East 33rd Street, Austin 21, Texas.
- *BARNES, WILLIAM H., Room 3047, National Research Council, Sussex Street, Ottawa, Canada.
- BARRETT, RICHARD L., Mesilla Park, New Mexico.
- *BARTH, TOM F. W., Department of Geology, University of Chicago, Chicago, Illinois.
- *BARTLETT, HELEN BLAIR, AC Spark Plug Company, Flint 2, Michigan.
- *BATEMAN, ALAN, M., Dept. of Geology, Yale University, New Haven, Connecticut.
- *BATES, THOMAS F., Dept. of Earth Sciences, Pennsylvania State College, State College, Pennsylvania.
- *BAUER, LAWSON H., Franklin, New Jersey.
- BAUM, JOSEPH A., Taos, New Mexico.
- BAUMANN, H. N., Research Dept., The Carborundum Co., Niagara Falls, New York.
- BAXTER, E. F., Calle Viamonte 470, Cordoba, Argentina.
- BAYNE, G. WALLACE, Department of Geology, University of Washington, Seattle 5, Washington.
- BAZHENOV, I. K., Kievskaja, D. 46, kv. 4, Tomsk, U.S.S.R.
- BEARD, E. H., The Imperial Institute, London, S.W. 7, England.
- BECK, CARL W., Dept. of Geology, University of New Mexico, Albuquerque, New Mexico.
- *BEHRE, CHARLES H., JR., Dept. of Geology, Columbia University, New York 27, N. Y.
- BELL, GORDON L., 44 West 21st South, Salt Lake City 5, Utah.
- *BELL, JAMES FORBES, 1510 Public Service Bldg., Portland 4, Oregon.

- BENTLEY, L. W., 220 Sterling Road, Toronto 3, Ontario, Canada.
- BERKELHAMER, LOUIS H., Ohmite Manufacturing Company, 4835 Flournoy Street, Chicago 44, Illinois.
- BERMAN, JOSEPH, 535 Fox Street, Denver 4, Colorado.
- BERNHEIMER, ALAN W., Dept. of Bacteriology, N.Y.U. College of Medicine, 477—1st Ave., New York, N. Y.
- *BERRY, LEONARD G., Dept. of Mineralogy, Queen's University, Kingston, Ontario, Canada.
- BETEKHTIN, PROF., Tshkalovskaja Ul., D. 21, kv. 38, Moscow 64, U.S.S.R.
- *BILLINGS, MARLAND P., Harvard University, Cambridge 38, Massachusetts.
- BINGHAM, E. BURRIS, 8436 Ramsgate, Los Angeles 45, California.
- BIREN, MRS. H. A., Brooklyn College, Bedford Ave., & Ave. H., Brooklyn, New York.
- BISH, JAMES H., 110 McAllister Street, Hanover, Pennsylvania.
- BJAREBY, GUNNAR, 147 Worthington Street, Boston 15, Massachusetts.
- BLANCHARD, ROLAND, Mount Isa Mines Ltd., Mount Isa, Queensland, Australia.
- BLANK, HORACE R., Dept. of Geology & Mineralogy, Southwestern University, Georgetown, Texas.
- BLOOM, H., RR 3, Box 161, Bass Lake, Indiana.
- BLONDEL, FERNAND A., 12 Rue de Bourgogne, Paris VII, France.
- BLOOM, JOSEPH B., 7810 Brewster Avenue, Philadelphia 42, Pennsylvania.
- BOCK, LUDWIG, 951 Alameda de Las Pulgas, Menlo Park, California.
- BOGUE, RICHARD G., Merrill, Oregon.
- BOKIJ, G. B., Knizhni Otdel Akad. Nauk. Ul. Kropotkina, 16, Moscow 34, U.S.S.R.
- BOOTH, OLIVER E., 907 Clinton Avenue, Des Moines 13, Iowa.
- BORGES, ANTONIO FARES, Caixa Postal No. 1907, Sao Paulo, Brazil.
- BORGSTROM, L. H., Mussigatan 3, Helsingfors, Finland.
- BOUSFIELD, JOHN C., 20 Arundel, St. Louis 5, Missouri.
- *BOWEN, NORMAN L., Geophysical Laboratory, 2801 Upton Street, N.W., Washington 8, D. C.
- *BOWLES, OLIVER, 5000 Massachusetts Ave., N.W., Washington 16, D. C.
- BOYNTON, A. G., Box 611, Boulder City, Nevada.
- BRADLEY, J. W., 4300 Budlong Avenue, Los Angeles 37, California.
- *BRADLEY, WM. F., Illinois State Geological Survey, Urbana, Illinois.
- *BRAMLETTE, MILTON N., Department of Geology, University of California, Los Angeles 24, California.
- BRANT, ARTHUR M., Lord Hall, Ohio State University, Columbus, Ohio.
- BRAY, D. M., 42 William Street, Roseville, N.S.W., Australia.
- BRECKE, ERVIN A., Rosiclare, Illinois.
- BRENDLER, W., Winterstrasse 4-8, Hamburg-Altona, Germany.
- BRINEMAN, JOHN H., Socony-Vacuum Oil Company de Venezuela, Apartado Aereo 4034, Apartado Nacional 1140, Bogotá, Colombia, South America.
- BROWN, ARTHUR H., R.F.D. Mission Road, Jessups, Maryland.
- *BROWN, JOHN S., c/o St. Joseph Lead Co., Bonne Terre, Missouri.
- BROWN, W. R., Dept. of Geology, University of Kentucky, Lexington 29, Kentucky.
- *BRUCE, E. L., Department of Mineralogy, Queen's University, Kingston, Ontario, Canada.
- BRUNK, C. C., 2809½ West 42nd Street, Los Angeles 43, California.
- BRYANT, W. M. D., R.D. 3, Silverside Road, Wilmington, Delaware.
- BUBERNAK, JOSEPH, 1220 Mine Street, Old Forge, Pennsylvania.
- BUCKLEW, HAROLD C., 1048 Broad Street, Newark, New Jersey.
- *BUCKLEY, HAROLD E., 100 Hazelhurst Road, Worsley, Manchester, England.

- *BUDDINGTON, ARTHUR F., Department of Geology, Princeton University, Princeton, New Jersey.
- *BUERGER, MARTIN J., Massachusetts Institute of Technology, Cambridge 39, Massachusetts.
- *BUERGER, NEWTON W., Dept. of Metallurgy, U. S. Naval Academy, Annapolis, Maryland.
- BUTE, BENNETT FRANK, Dept. of Geology, University of South Carolina, Columbia, South Carolina.
- *BULLARD, FRED M. 903 West 30th Street, Austin, Texas.
- BULLOCK, KENNETH C., Dept. of Geology, Brigham Young University, Provo, Utah.
- BUNTON, PAUL B., 2900 Connecticut Avenue, N.W., Washington 8, D. C.
- *BURBANK, WILBUR S., 3346 Runnymede Place, N.W., Washington 15, D. C.
- BURFOOT, JAMES DABNEY, JR., Department of Geology, Cornell University, Ithaca, New York.
- BURNHAM, G. E., 128½ S. Encinitas Avenue, Monrovia, California.
- BURTON, JAMES E., 115 North Kendall, Topeka, Kansas.
- BUTLER, E. S., 408 Archer Street, Houston 9, Texas.
- BUTLER, G. M., JR., Research Dept., Carborundum Company, Niagara Falls, New York.
- *BUTLER, G. MONTAGUE, Box 4186, University Station, Tucson, Arizona.
- BUTLER, JOHN W., JR., c/o Phillips Venezuelan Oil Company, Apartado 1031, Caracas, Venezuela.
- *BUTLER, ROBERT D., Bethlehem Steel Company, Bethlehem, Pennsylvania.
- *BUTTGENBACH, HENRY J., 182 Avenue F. D. Roosevelt, Bruxelles, Belgium.
- BYERS, FRANK M., JR., U. S. Geological Survey, Washington 25, D. C.
- BYRON, J. E., 1240 Pearl Street, Boulder, Colorado.
- CALLAHAN, WILLIAM H., Franklin, New Jersey.
- *CALVER, JAMES L., 1553 Cristobal Drive, Los Robles, Tallahassee, Florida.
- CALVERT, EARL L., 1528 Ardenale Ave., San Gabriel, California.
- CAMARGO, WILLIAM G. R. DE, Al. Glette, 463, Sao Paulo, S. P., Brazil.
- *CAMERON, EUGENE N., U. S. Geological Survey, Washington 25, D. C.
- *CAMPBELL, CHARLES D., U. S. Geological Survey, Northport, Washington.
- *CAMPBELL, IAN, California Institute of Technology, Pasadena 4, California.
- CANAL, PAUL, 4 Place Bir-Hacheim, Rueil-Malmaison (S & O), France.
- *CANNON, RALPH S., JR., U. S. Geological Survey, Washington 25, D. C.
- CAPLAN, ALLAN, 2 West 46th Street, New York 19, N. Y.
- CARDOSO, D. GABRIEL M., Apartado 108, Santiago de Compostela, Galicia, Spain.
- CARGILLE, R. P., 118 Liberty Street, New York 6, N. Y.
- CARL, HOWARD F., Highland, Howard County, Maryland.
- *CAROBI, GUIDO, Istituto de Mineralogia della Universita, Florence, Italy.
- CARTER, JOE O., Box 574, Marshall, Texas.
- *CHAPMAN, CARLETON, A., Department of Geology, University of Illinois, Urbana, Illinois.
- *CHAPMAN, RANDOLPH, Dept. of Geology, The Johns Hopkins University, Baltimore 18, Maryland.
- *CHAYES, FELIX, Geophysical Laboratory, 2801 Upton Street, N.W., Washington 8, D. C.
- CHESLEY, FRANK G., Central Research Laboratories, Inc., Red Wing, Minnesota.
- CHESLEY, RICHARD B., 50 Pratt Street, Reading, Massachusetts.
- CHESTERMAN, CHARLES W., 1066 Keith Avenue, Berkeley, California.
- CHIDESTER, ALFRED H., 2043 3X Avenue, East Moline, Illinois.
- CHOQUETTE, ARTHUR, 1877 Jeanne d'Arc Street, Maisonneuve, Montreal, P.Q., Canada.
- CHUTE, NEWTON E., Department of Geology, Syracuse University, Syracuse, N. Y.

- CLABAUGH, STEPHEN E., Dept. of Geology, University of Texas, Austin 12, Texas.
- CLAFFEY, MRS. ESTHER W., Naval Research Laboratory, Crystal Section, Bldg. 3, Washington 25, D. C.
- *CLARINGBULL, G. F., Dept. of Mineralogy, British Museum (Natural History), London, S.W. 7, England.
- CLAUSEN, HANS, Mineralogical Museum, Oster Voldgade 7, Copenhagen, K., Denmark.
- *COATS, ROBERT, Alaskan Branch, Geological Survey, Washington 25, D. C.
- COBOLEV, V. S., Ul. Kozubinskogo, Dom. 11, kv. 3, Lvov, U.S.S.R.
- *COLBURN, BURNHAM S., Greystone Court, Biltmore, North Carolina.
- *COLBURN, WILLIAM B., P.O. Box 456, Rancho Santa Fe, California.
- COLE, G. THURSTON, Rumford Point, Maine.
- COMEFORO, JAY EUGENE, 609 West Main Street, Urbana, Illinois.
- CONNER, GRADY, Caroleen, North Carolina.
- COOK, MRS. KATHRYN H., 493 South Firestone Blvd., Akron, Ohio.
- COOK, ROGER H., 1213 12th Street, Golden, Colorado.
- COOKE, H. R., JR., Chile Exploration Co., Chuquicamata, Chile, South America.
- *COOKE, S. R. B., Minnesota School of Mines, Minneapolis 14, Minnesota.
- COOLEY, MARY E., 703 South Forest Ave., Ann Arbor, Michigan.
- *COOPER, JOHN R., U. S. Geological Survey, Washington 25, D. C.
- COPLIN, FRANK, Candle, Alaska.
- *CORBETT, CLIFTON S., 1102 Talon Avenue, Calgary, Alta., Canada.
- CORRENS, CARL, c/o Dr. H. Winkler, Geology Dept., The University, Leeds 2, England.
- COTTER, PERRY G., 76 Pine Road, Norris, Tennessee.
- CRAWFORD, ARTHUR L., 1067 East Fifth St. S., Salt Lake City, Utah.
- *CRAWFORD, R. D., 1050 Tenth Street, Boulder, Colorado.
- CREITZ, ELLIS E., Drawer L, University, Alabama.
- CRIBBS, RICHARD E., Forest City, Iowa.
- CRIPPEN, RICHARD A., JR., Division of Mines, Ferry Building, San Francisco, California.
- CROPPER, WALLACE J., 4410 Cayuga Avenue, New York 63, N. Y.
- CRUMP, ROBERT M., Box 88, Star Lake, New York.
- CRUNDEN, A. B., 54 Edgemont Road, Montclair, New Jersey.
- CUMMINS, A. B., Cedar Crest Road, Bound Brook, New Jersey.
- *CURRIER, LOUIS W., U. S. Geological Survey, Washington 25, D. C.
- CUTHBERT, F. LEICESTER, Baroid Sales Division, National Lead Company, City National Bank Bldg., Houston 2, Texas.
- DAGGETT, E. B., 392 West 1st North, Richfield, Utah.
- DAKE, H. C., 329 S. E. 32nd Avenue, Portland 15, Oregon.
- DANNER, WILBERT R., 11025 38th N. E., Seattle 55, Washington.
- DARNEAL, ROBERT L., Box 832, Stanford University, California.
- DAVIDSON, CHARLES F., Geological Survey and Museum, London, S.W. 7, England.
- DAVIDSON, NORMAN, 5611 Fifth Street, N.W., Washington 11, D. C.
- DAVIDSON, STANLEY C., 152 Wembley Drive, Sudbury, Ontario, Canada.
- DAVIS, DONALD W., RFD 1, Katonah, New York.
- DAVIS, GORDON L., 4115 Wisconsin Ave., N.W., Washington 8, D. C.
- DAVIS, HARRY T., Curator of Geology, North Carolina State Museum, Raleigh, North Carolina.
- DAVIS, KENNETH, Hibbs Building, Washington, D. C.
- DE BRETTEVILLE, A. P., JR., Box 645, Red Bank, New Jersey.
- DEIDRICK, ROBERT O., 7051 Broadway Terrace, Oakland, California.
- DE LIMA, PLINIO, Rua Vitorino Carmillo 565, Sao Paulo, Brazil.

- DENGO, GABRIEL, Department of Geology, Princeton University, Princeton, New Jersey.
- DENNEN, WILLIAM, 226 Pleasant Street, Arlington, Massachusetts.
- DENNING, REYNOLDS M., 1015 E. Houghton Ave., Houghton, Michigan.
- DENNY, M. V., Mineralogical Laboratory, University of Michigan, Ann Arbor, Michigan.
- DE REWAL, FRANK J., 276 West Fishers Ave., Philadelphia 20, Pennsylvania.
- DESMOND, THOMAS C., 94 Broadway, Newburgh, New York.
- DEUL, MAURICE, U. S. Geological Survey, Section of Geochemistry and Petrology, Washington 25, D. C.
- DEVORE, GEORGE W., Box 180, Laramie, Wyoming.
- DIETERICH, J. F., 3724 Vantage Ave., North Hollywood, California.
- DEITZ, RALPH W., Box N690, N.O.T.S., China Lake, California.
- DIETZ, ROBERT SINCLAIR, Navy Electronics Laboratory, San Diego 52, California.
- DODGE, NELSON B., Concrete Research Division, Waterways Experiment Station, P.O. Box 2171, Clinton, Mississippi.
- *DODGE, THEODORE A., 109 West Alameda Street, Tucson, Arizona.
- DOEGLAS, D. J., Landbouwhogeschool, Afdeling Geologie & Mineral., Wageningen, Holland.
- *DONNAY, JOSEPH D. H., Dept. of Geology, Johns Hopkins University, Baltimore 18, Maryland.
- DOSS, CARSON L., P.O. Box 541, Golden, Colorado.
- DOUGLASS, H. M., 3036 N. E. Everett, Portland 15, Oregon.
- DRAEGER, R. H., Capt. (MC), U.S.N., Naval Medical Research Institute, Bethesda 14, Maryland.
- DRAISIN, WILBURT M., 77 Tanark Road, Brookline 46, Massachusetts.
- DRAKE, CURTIS C., 2061 South Clarkson Street, Denver 10, Colorado.
- DREYER, ROBERT M., Dept. of Geology, University of Kansas, Lawrence, Kansas.
- *DRUGMAN, JULIEN, 33 Rue Edmond Picard, Uccle (Brabant), Belgium.
- DUBITSKY, ROY H., Aggieland Inn, College Station, Texas.
- DUERSMITH, I. J., 933 Spruce Street, Columbia, Pennsylvania.
- DUFFENDACK, O. S., Irvington Research Laboratory, North American Philips Company, Dobbs Ferry, New York.
- DUPLIN, V. J., JR., The Babcock & Wilcox Company, Alliance, Ohio.
- DUPONT, JAMES M., Myersville Road, Chatham, New Jersey.
- EARHART, HELEN S., Laboratory, Socony-Vacuum Oil Co. of Colombia, Apartado Nacional 1140, Bogotá, Colombia.
- EASON, F. B., Box 348, Wilson, North Carolina.
- EBBUTT, FRANK, 173 Glenrose Avenue, Toronto, Ontario, Canada.
- EBERLEIN, G. DONALD, P.O. Box #7, Los Gatos, California.
- *ECKEL, EDWIN B., Box 2858, Lakewood Branch, Denver 15, Colorado.
- *ECKERMANN, HARRY VON, Edeby, Sparreholm, Sweden.
- EDDY, C. N., National State Bank, Boulder, Colorado.
- EHRMANN, MARTIN L., 741 So. Ridgeley Drive, Los Angeles 36, California.
- EISENBERG, JEROME, 77 Victoria Street, Revere 51, Massachusetts.
- ELIAS, HELEN V., 416 Grand Street, New York 2, New York.
- ELISEEV, N. A., Nab. Kutuzova 26, kv. 14, Leningrad, U.S.S.R.
- *ELLESTAD, REUBEN B., 715 Fifth Street, S.E., Minneapolis, Minnesota.
- *ELLSWORTH, H. V., Canada Geological Survey, Ottawa, Canada.
- ELMER, LEWIS, P.O. Box 1984, Boise, Idaho.
- ELWELL, WILBUR J., 2 Duck Street, Danbury, Connecticut.

- *EMMONS, RICHARD C., University of Wisconsin, Madison, Wisconsin.
- ENGEL, ALBERT E. J., Dept. of Geology, California Institute of Technology, Pasadena, California.
- ENGEL, RENE, Los Angeles County Museum, Exposition Park, Los Angeles 7, California.
- ENLOWS, HAROLD E., The University of Tulsa, Seventh and College, Tulsa 4, Oklahoma.
- ERDMANN, CHARLES E., c/o U. S. Geological Survey, P O. Box 1827, Great Falls, Montana.
- EVANOFF, PHILIP, 1842 Butler Pike, Conshohocken, Pennsylvania.
- EVANS, HOWARD T., JR., 850 Massachusetts Ave., Apt. 10, Cambridge, Massachusetts.
- EVANS, M. N., Jungo, Nevada.
- FACKLER, WILLIAM C., P.O. Box 184, College, Alaska.
- *FAESSLER, CARL, Université Laval, Boulevard de l'Entente, Quebec, Canada.
- *FAHEY, JOSEPH J., U. S. Geological Survey, Washington 25, D. C.
- FAICK, JOHN N., Hanover, New Mexico.
- *FAIRBAIRN, HAROLD W., Department of Geology, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.
- *FANKUCHEN, I., Polytechnic Institute of Brooklyn, Brooklyn, New York.
- FARWELL, FRED W., 67 Highland Avenue, South Norwalk, Connecticut.
- *FAUST, GEORGE T., 1803 Capitol View Ave., Silver Spring, Maryland.
- FEDOCK, MICHAEL P., 1410 16th Street, N.W., Canton 3, Ohio.
- *FENNER, CLARENCE N., 64 Broad Street, Clifton, New Jersey.
- FERGUSON, J. A., 702 West Washington Street, Urbana, Illinois.
- FERGUSON, R. B., Department of Geology, University of Manitoba, Winnipeg, Canada.
- *FETTKE, CHARLES R., 1118 Wightman Street, Squirrel Hill Sta., Pittsburgh 17, Pa.
- FILER, ALVIN V., JR., 201 West 77th Street, New York 24, N. Y.
- FINCH, JAMES, Dominion Laboratory, Sydney St. W., Wellington N. 1, New Zealand.
- FINLAY, G. R., c/o Norton Company, Chippawa, Ontario, Canada.
- *FISHER, D. JEROME, Dept. of Geology, University of Chicago, Chicago 37, Illinois.
- *FISHER, LLOYD W., Department of Geology, Bates College, Lewiston, Maine.
- FISHER, ROBERT B., 200 West 18th Street, Rolla, Missouri.
- FISK, HENRY G., University of Wyoming, Laramie, Wyoming.
- FLACK, WYLIE H., 333 Borbeck St., Philadelphia 11, Pennsylvania.
- FLAGG, A. L., Box 2345, Phoenix, Arizona.
- FLEENER, F. L., 222 South Park Road, Joliet, Illinois.
- FLEISCHER, ARTHUR, Box 1327, Hartford 1, Connecticut.
- *FLEISCHER, MICHAEL, U. S. Geological Survey, Washington 25, D. C.
- FONTALTABE, MANUEL, Salon No. 2-20, Barcelona, Spain.
- *FORD, HUGH ALEXANDER, 736 Riverside Drive, Apt. 6-C, New York 31, N. Y.
- FORMAN, S. A., Department of Geological Sciences, University of Toronto, Toronto, Canada.
- *FOSHAG, WILLIAM F., U. S. National Museum, Washington, D. C.
- FOSTER, MARGARET D., U. S. Geological Survey, Washington 25, D. C.
- FOSTER, P. A., 4730 Angeles Vista Blvd., Los Angeles 43, California.
- FOSTER, PHILIP C., R. D. 1, South Berwick, Maine.
- FOSTER, RICHARD K., 431 Bucknell Street, Pittsburgh, Pennsylvania.
- FOSTER, WILDER D., 4800 Forbes Street, Pittsburgh 13, Pennsylvania.
- FOSTER, WILFRID R., Champion Spark Plug Co., 8525 Butler Ave., Detroit 11, Michigan.
- FOX, PORTLAND P., P.O. Box 31, Charleston, Tennessee.
- FRANK-KAMENEZKIJ, V. A., Stremjannaja Ul. Dom. 18, kv. 2, Leningrad 25, U.S.S.R.

- *FRASER, DONALD MCCOY, Geological Department, Bethlehem Steel Co., Bethlehem, Pennsylvania.
- *FRASER, HORACE J., Box C, Falconbridge, Ontario, Canada.
- FRÉCHETTE, V. D., N. Y. State College of Ceramics, Alfred, New York.
- FREED, OLYN, 509 Evans Avenue, Reno, Nevada.
- FREEZE, ARTHUR C., Consolidated Mining & Smelting Co., Kimberley, British Columbia, Canada.
- FRETZ, A. HENRY, 42 West Market Street, Bethlehem, Pennsylvania.
- FRIES, CARL JR., U. S. Geological Survey, Washington 25, D. C.
- *FRONDEL, CLIFFORD, 12 Geological Museum, Oxford Street, Cambridge 38, Massachusetts.
- FRUEH, ALFRED J., JR., Dept. of Geology, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.
- *FULLER, RICHARD E., 1642 Federal Avenue, Seattle, Washington.
- FUMI, FAUSTO, c/o Prof. Seitz, Carnegie Inst. of Technology, Pittsburgh, Pennsylvania.
- FURQUE, SR. GUILLERMO, Independencia 1389, Buenos Aires, Argentina.
- *GABRIEL, ALTON, U. S. Bureau of Mines, College Park, Maryland.
- GAD, GAMAL M., 50 El-Naser Street, Manchist El-Sadr, Cairo, Egypt.
- *GALBRAITH, F. W., Dept. of Geology, University of Arizona, Tucson, Arizona.
- *GALLAGHER, DAVID, 907 Rood Avenue, Grand Junction, Colorado.
- GALLONI, ING. ERNESTO, Yermal 1763, Buenos Aires, Argentina.
- GARRIDO, J., Lagasca 123, Madrid, Spain.
- GATES, ROBERT M., Science Hall, Madison, Wisconsin.
- *GAUDIN, A. M., Room 8-211, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.
- GAULT, H. RICHARD, Dept. of Geology, Lehigh University, Bethlehem, Pennsylvania.
- GENTRY, HAROLD, 830 West Bond Street, Denison, Texas.
- GEORGALAS, GEORGE C., 25 Pergamou, Athens, Greece.
- GEORGE, D'ARCY R., King Street, Littleton, Massachusetts.
- GEORGE DON M., JR., 1149 South Second Street, Alhambra, California.
- *GIANELLA, VINCENT P., Mackay School of Mines, Reno, Nevada.
- GIFFORD, H. PAXSON, c/o Hamilton Watch Company, Crust. & Abras. Res. Lab., Lancaster, Pennsylvania.
- GIFFORD, JAMES C., Box 924, Gunnison, Colorado.
- GILLESPIE, T. B., Box 290, Palatka, Florida.
- GILLINGHAM, THOMAS E., 511 McKinley Ave., Kellogg, Idaho.
- *GILLSON, JOSEPH L., 8058 duPont Building, Wilmington, Delaware.
- *GILLULY, JAMES, Department of Geology, University of California at Los Angeles 24, California.
- GINSBERG, A. S., Aptekarskij prosp. 6 kv. 35, Leningrad 22, U.S.S.R.
- GLASS, HERBERT D., 102 East Stoughton Street, Champaign, Illinois.
- *GLASS, JEWELL J., U. S. Geological Survey, Washington 25, D. C.
- *GODDARD, EDWIN N., U. S. Geological Survey, Washington 25, D. C.
- GOETTMAN, FRANKLIN P., 4713 Smick Street, Philadelphia 27, Pennsylvania.
- *GOLDICH, SAMUEL S., Department of Geology, University of Minnesota, Minneapolis 14, Minnesota.
- GOLDSMITH, J. R., Department of Geology, University of Chicago, Chicago 37, Illinois.
- GONZALES-BONORINO, SR. FELIX, Direccion de Minas y Geologia, Peru 562, Buenos Aires, Argentina, S. A.
- GOOD, RICHARD STANDISH, 410 S. Frazier Street, State College, Pennsylvania.
- GOODMAN, CLARK, 77 Massachusetts Avenue, Cambridge, Massachusetts.

- *GOODSPEED, GEORGE E., Dept. of Geology, University of Washington, Seattle, Washington.
- GORDON, ELEANOR, Rt. 9, Box 470, Salem, Oregon.
- *GORDON, SAMUEL G., Philadelphia Academy of Natural Sciences, Logan Circle, Philadelphia, Pennsylvania.
- *GORDON, WILLIAM T., Kings College, Strand, London W.C. 2, England.
- GORING, ARTHUR W., Box 183, Ruth, Nevada.
- GOUDEY, HATFIELD, Box 401, Yerington, Nevada.
- *GRAHAM, R. P. D., McGill University, Montreal, Canada.
- GRAHL, HARRY, 885 Cauldwell Avenue, Bronx, New York.
- GRANT, R. C., 2524 Benvenue Ave., Berkeley 4, California.
- *GRATON, LOUIS C., Rotch Building, Cambridge 38, Massachusetts.
- *GRAW, OLIVER R., Department of Geology, Missouri School of Mines, Rolla, Missouri.
- GREENE, KENNETH T., 746 Gaylord Street, Denver 6, Colorado.
- *GREIG, JOSEPH W., Geophysical Laboratory, 2801 Upton St., N.W., Washington 8, D. C.
- *GRIFFITHS, JOHN CEDRIC, Dept. of Earth Sciences, Pennsylvania State College, State College, Pennsylvania.
- GRIFFITHS, WALLACE R., Department of Geology, University of Colorado, Boulder, Colorado.
- GRIGORIEVE, D. P., 15 Linia, 34 kv. 15, Leningrad 178, U.S.S.R.
- GRIGORIEVE, I. F., Knizhnyj Odel AN, Ul. Kropotkina, 16, Moscow 34, U.S.S.R.
- *GRIM RALPH E., Illinois Geological Survey, Urbana, Illinois.
- GROGAN, ROBERT M., Illinois State Geological Survey, Urbana, Illinois.
- GROSS, EUGENE B., 755 15th Street, Boulder, Colorado.
- GROSSMAN, IRVING, Dept. of Geology, University of North Dakota, Grand Forks, N. D.
- *GROUT, FRANK F., Dept. of Geology, University of Minnesota, Minneapolis, Minnesota.
- GRUEY, MERLE N., 189 Vine, Geneva, Ohio.
- *GRUNER, JOHN W., Dept. of Geology, University of Minnesota, Minneapolis, Minnesota.
- GRUNIG, J. K., U. S. Geological Survey, Silver City, New Mexico.
- GUERCI, MRS. IRMGARD A., 2718 Bainbridge Ave., New York 58, N. Y.
- GUMMER, WILFRID K., 815 Fifth Street, Arvida, Quebec, Canada.
- GUTENSON, OTTO, 3116 Greenwich Ave., Chattanooga, Tennessee.
- *GYSIN, M. E., Laboratoire de Minéralogie de l'Université, Quai de l'Ecole-de-Médecin, Genève, Switzerland.
- HADDOCK, WILLIAM J., 7700 Boeing Avenue, Los Angeles 45, California.
- HAECKER, A. J., JR., Georgia Kaolin Co., 1185 Nary Street, Elizabeth, New Jersey.
- *HAFF, JOHN C., Department of Geology, Mount Holyoke College, South Hadley, Massachusetts.
- HAGNER, ARTHUR F., Dept. of Geology, University of Illinois, Urbana, Illinois.
- HALBOUTY, M. T., Suite 729-32, Shell Building, Houston 2, Texas.
- HALL, F. P., 206 Granger Road, Syracuse 9, New York.
- *HALLIMOND, ARTHUR FRANCIS, Geological Survey and Museum, Exhibition Road, South Kensington, London, S.W. 7, England.
- HALSEY, J. H., Bacon Hall, University of California, Berkeley, California.
- HAM, WILLIAM EUGENE, State Geological Survey, Norman, Oklahoma.
- HAMBLSTON, WILLIAM W., Department of Geology, Kansas University, Lawrence, Kansas.
- HAMBURGER, GABRIELLE E., Room 24-320, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.
- HANLEY, JOHN B., Section of Non-Metalliferous Geology, U. S. Geological Survey, Washington 25, D. C.

- HANSON, HARRY, 5319 York Boulevard, Los Angeles, California.
- *HARCOURT, GEORGE ALAN, Copper Cliff, Ontario, Canada.
- HARD, CARL G., 120 Glover Street, Southbridge, Massachusetts.
- HARRISON, GEORGE L., Palacios, Texas.
- HASSAN, MOHAMED N., 2355 Hilgard Avenue, Berkeley 4, California.
- HATCH, ROBERT A., U. S. Bureau of Mines, Norris, Tennessee.
- HATFIELD, MALCOLM, Probate Court, St. Joseph, Michigan.
- HAUZE, GEORGE E., P.O. Box 326, Fairlawn, New Jersey.
- *HAWKINS, A. C., 1445 East 7th Street, Plainfield, New Jersey.
- HAWLEY, F. G., 1624 E. Fifth Street, Tucson, Arizona.
- *HAWLEY, JAMES E., Queen's University, Kingston, Ontario, Canada.
- HAYES, JULIAN LEE, P.O. Box 751, Park City, Utah.
- HAYNES, O. V., R.F.D. 3, Giffen Road, Wooster, Ohio.
- HEARNE, L. F., Box 589, Wheeling, West Virginia.
- HEINEMAN, ROBERT E. S., 20 Calle Conquista, Tucson, Arizona.
- *HEINRICH, E. WM., Department of Mineralogy, University of Michigan, Ann Arbor, Michigan.
- HENDERSON, DONALD M., Dept. of Geology, University of Illinois, Urbana, Illinois.
- *HENDERSON, EDWARD P., U. S. National Museum, Washington, D. C.
- *HENDRICKS, STERLING B., 1118 Dale Drive, Silver Spring, Maryland.
- HENRY, NORMAN F. M., Dept. of Mineralogy and Petrology, University of Cambridge, Downing Street, Cambridge, England.
- *HESS, FRANK L., 5509 Roosevelt Street, Bethesda 14, Maryland.
- *HESS, HARRY H., Dept. of Geology, Princeton University, Princeton, New Jersey.
- HENRY, PATRICIA A., 826 Tappan Street, Ann Arbor, Michigan.
- HENTSCHEL, H. W., DeKalb Pike, Washington Square, R.D. 3, Norristown, Pennsylvania.
- HERTEL, FRANCIS, JR., Menlo Jr. College, Menlo Park, California.
- HERZENBERG, ROBERT, Casilla 23, Oruro, Bolivia, South America.
- *HEWETT, DONNEL F., 1460 Rose Villa Street, Pasadena, California.
- HEWITT, D. F., 1195 Avenue Road, Toronto, Ontario, Canada.
- HEYL, ALLEN V., JR., Dept. of Geology, Princeton University, Princeton, New Jersey.
- *HEYL, GEORGE R., Apartado 889, Creole Petroleum Corporation, Caracas, Venezuela, S. A.
- HEYMAN, NATHAN, 642 Fifth Avenue, New York City, New York.
- HICKOK, WILLIAM O., IV, R.D. 3, Linglestown, Pennsylvania.
- HIGAZY, RIAD A., Geology Dept., Faculty of Science, Farouk I Univ., Moharram Bey, Alexandria, Egypt.
- HILL, H. STANTON, Geology Department, Pasadena City College, Pasadena 4, California.
- HILL, JEFF, 2210 St. Marys Street, Raleigh, North Carolina.
- HILL, V. D., Route 7, Box 188, Wooster, Ohio.
- HILL, WILLIAM L., 321 Ingraham Street, N.W., Washington 11, D. C.
- HILLS, RALPH F., 18 Greenwood Avenue, Bloomfield, Connecticut.
- HILMY, M., Geology Dept., University of Chicago, Chicago 37, Illinois.
- HINCKLEY, ARTHUR T., 937 Harrison Avenue, Niagara Falls, New York.
- HO, T. L., Department of Geology, National University of Shanting, Tsingtao, China.
- *HODGE, EDWIN T., 2915 Luray Terrace, N.W., Portland, Oregon.
- *HOLDEN, GUERDON S., Plain Dealer Building, Cleveland, Ohio.
- HOLLON, CHARLES T., 1910 Tuam Avenue, Houston 4, Texas.
- *HOLMES, ARTHUR, Univ. of Edinburgh, Grant Institute of Geology, King's Buildings, West Mains Road, Edinburgh 9, Scotland.

- HOLMES, MRS. M. A., c/o Chase National Bank, Bushhouse, Aldwych, London, W. C. 2, England.
- *HOLMES, RALPH J., Department of Geology, Columbia University, New York 27, N. Y.
- HOLSER, WILLIAM T., Dept. of Geology, McGraw Hall, Cornell University, Ithaca, New York.
- HOOKE, MARJORIE, 4110 3rd Road North, Arlington, Virginia.
- HORN, AUBREY E., c/o Associated Tin Mines of Nigeria, Ltd., P.O. Barrikin Ladi, Plateau Province, Nigeria.
- HOSE, HEATH ROYDON, Aluminum Laboratories, 1800 Sun Life Building, Montreal, Quebec, Canada.
- HOWARD, ELDON O., Box 294, Watervliet, Michigan.
- HOWELLS, LEWIS W., Orefield, R.F.D. #1, Pennsylvania.
- *HOWLAND, ARTHUR L., Department of Geology, Northwestern University, Evanston, Illinois.
- HUBBARD, BELA, 1405 E. Kleindale Road, Tucson, Arizona.
- HUFNAGEL, ALVIN A., 1150 Carroll Street, Brooklyn 25, New York.
- HUGILL, WILLIAM, Langham House, Field Road, Alsager, Cheshire, England.
- HUMMEL, FLOYD A., Pennsylvania State College, Dept. of Mineral Technology, State College, Pennsylvania.
- *HUNT, WALTER F., Mineralogical Laboratory, University of Michigan, Ann Arbor, Michigan.
- *HURLBUT, CORNELIUS S., JR., Harvard University, Cambridge 38, Massachusetts.
- HURST, THOMAS L., 444 Lafayette, Palmerton, Pennsylvania.
- HUSTED, JOHN E., Box 1600 Midland, Texas.
- *HUTTON, C. OSBORNE, Dept. of Mineral Sciences, Stanford University, Palo Alto, California.
- HYDE, FRANK, Humbug Gold Mines, Castle Hot Springs, Arizona.
- *INGERSON, EARL, U. S. Geological Survey, Washington 25, D. C.
- INGRAM, W. F., P.O. Box 23, 433 West Taylor Street, Griffin, Georgia.
- *INSLEY, HERBERT, National Bureau of Standards, Washington 25, D. C.
- IRWIN, WILLIAM H., 215 East 19th Ave., Denver 5, Colorado.
- ISOFF, A., Dept. of Geology, Idaho State College, Pocatello, Idaho.
- IVER, L. A. N., Patna University, Bankipore P.O., Patna, India.
- JACKEL, ROLAND D., 2000 S. Randolph Street, Arlington, Virginia.
- JACKSON, KERN C., Unit 47D Badger, Wisconsin.
- JACOBS, ELBRIDGE C., University of Vermont, Burlington, Vermont.
- JACOBS, LOUIS J., The Obermayer Co., 2563 W. 18th Street, Chicago 8, Illinois.
- JAE, JAMES F., 5510 Waterman Avenue, St. Louis 12, Missouri.
- JAFFE, ARTHUR, 3212 W. Dauphin Street, Philadelphia, Pennsylvania.
- JAFFE, HOWARD W., 5704—4th Street, N.W., Washington 11, D. C.
- JAMES, HAROLD L., U. S. Geological Survey, Box 15, Iron River, Michigan.
- JARRELL, OSCAR W., 1752 S. Shenandoah Street, Los Angeles 35, California.
- JEFFRIES, CHARLES D., Dept. of Agronomy, Agricultural Building, State College, Pennsylvania.
- JENSEN, DAVID E., 199 East Brook Road, Pittsford, New York.
- JOHANSSON, FREDERICK V., 96 Boutelle Street, Leominster, Massachusetts.
- *JOHNSON, J. HARLAN, Colorado School of Mines, Golden, Colorado.
- JOHNSON, SARAH C., 5112 Connecticut Ave., N.W., Apt. 301, Washington 5, D. C.
- JOHNSON, W. M., R.F.D. 6, Knoxville, Tennessee.

- *JOHNSTON, R. A. A., 112 Old Forest Hill Road, Toronto 10, Canada.
JOHNSTON, W. G., Leeville, Ontario, Canada.
- *JOHNSTON, WILLIAM D., JR., U. S. Geological Survey, Washington 25, D. C.
- *JOLLIFFE, ALFRED W., Bureau of Economic Geology, Canada Geological Survey, Ottawa, Canada.
- JONES, GARDNER H., 8 Hill Street, Lakeport, New Hampshire.
- KADEY, FREDERIC L., JR., Carnegie-Illinois Steel Corporation, Research Laboratory, 210 Semple Street, Pittsburgh 13, Pennsylvania.
- KAIMAN, S., 552 Booth Street, Ottawa, Canada.
- KALEY, MARY ELIZABETH, California Research Corp., Box 543, Whittier, California.
- KARAGEORGE, ELISSEOS D., Mineralogy Laboratory, University of Athens, F. Roosevelt Ave., Athens, Greece.
- KARRER, SEBASTIAN, c/o Milwaukee Gas Specialty Co., 730 N. Jackson St., Milwaukee, Wisconsin.
- KASPAR, JAN, Vhopkach 13, Praha 13, Czechoslovakia.
- KAUFFMAN, A. J., JR., 1131 No. Tenth Street, Corvallis, Oregon.
- KAZAZIAN, AVEDIA M., Casilla No. 240, Antofagasta, Chile.
- *KEEVIL, NORMAN BELL, 11 Jordan Street, Toronto, Ontario, Canada.
- KEITH, MAC L., Geophysical Laboratory, 2801 Upton Street, N. W., Washington 8, D. C.
- *KELLER, WALTER D., 208 Swallow Hall, Columbia, Missouri.
- *KELLEY, WALTER P., 120 Hilgard Hall, University of California, Berkeley 4, California.
- KEMP, MR. and MRS. C. E., Saulte Ste. Marie Branch, Michigan College of Mining & Technology, Sault Ste. Marie, Michigan.
- *KENNEDY, GEORGE C., Lowell G-34, Harvard University, Cambridge 38, Massachusetts.
- *KENNEDY, WILLIAM Q., Dept. of Geology, University of Leeds, Leeds 2, England.
- KEOUGH, M., P.O. Box 44, Que Que, Southern Rhodesia.
- *KERR, PAUL F., Dept. of Geology, Columbia University, New York 27, New York.
- KESSLER, CHARLES N., No. 3 Berg Apts., Helena, Montana.
- KIDWELL, ALBERT L., Dept. of Geology, University of Chicago, Chicago, Illinois.
- KIENREICH, JOS. A., Sackstrasse 6, Graz, Austria.
- KIETZ, ADOLPH, Box 225, R.F.D. 4, Bellevue, Washington.
- KING, MAURICE A., 2839 Abner Place, St. Louis, Missouri.
- KING, MYRLE E., 3102 West 36th Avenue, Denver, Colorado.
- KIRKPATRICK, ALAN F., 145 Frederick Street, Stamford, Connecticut.
- *KLEIN, ALBERT A., Norton Company, Worcester, Massachusetts.
- KLEIN, GILBERT E., Engineering Laboratory, Burgess Battery Company, Freeport, Illinois.
- KLEIN, IRA E., c/o Geology Division, Bureau of Reclamation, Sacramento, California.
- KNABE, WILLIAM C., 3853 North Gratz Street, Philadelphia, Pennsylvania.
- KNIZEK, J. O., Apartado 1402, Mexico, D. F., Mexico.
- *KNOPF, ADOLPH, Dept. of Geology, Yale University, New Haven, Connecticut.
- KOCH, GEORGE S., JR., Dept. of Geology, Johns Hopkins University, Baltimore 18, Maryland.
- KOCK, E. L., c/o Geo. W. Gates & Co., Franklin Square, L. I., N. Y.
- KOEBEL, CHARLES J., 9456 Grinnell Street, Detroit 13, Michigan.
- KONYVKERESKEDES, KILIAN, Budapest IV, Haris Koz 2, Hungary.
- *KOSCHMANN, A. H., Room 230 New Customhouse, Denver 2, Colorado.
- KOTLER, A. F., Vyzkumny ustav pro drahokamy v Turnove, Jiraskova 133, Czechoslovakia.

- *KRAUS, EDWARD H., Mineralogical Laboratory, University of Michigan, Ann Arbor, Michigan.
- KRAUSE, IGNACY J. T., Ulica Ludwika Rzepeckiego 45, Poznan, Poland.
- *KRISHNAN, MAHARAJAPURAM SITARAM, 27 Chowringhee, Calcutta, India.
- KUENSTLER, WALTER E., 410 Lafayette Ave., Cliffside Park 8, New Jersey.
- KUHN, TRUMAN H., Dept. of Geology, Colorado School of Mines, Golden, Colorado.
- KULL, SRTA. V., Perú 562, Buenos Aires, Argentina.
- KULP, J. LAURENCE, Dept. of Geology, Columbia University, New York 27, New York.
- KUPAS, JULIUS, Baia Mare-Bagybanya, Roumania.
- KURBATOV, JOANN D., Dept. of Physics, Ohio State University, Columbus, Ohio.
- KUTINA, JAN, Mineralogical Institute, Charles University, Albertov 6, Praha II, Czechoslovakia.
- LADOO, RAYMOND B., 42 Huntington Road, Newton 58, Massachusetts.
- *LANDES, KENNETH K., Geology Department, University of Michigan, Ann Arbor, Michigan.
- LANGFORD, LAWRENCE, P.O. Box 1673, Billings, Montana.
- LANGTON, JAMES L., Bettles, Alaska.
- *LARSEN, ESPER S., JR., 59 Orchard Street, Belmont, Massachusetts.
- *LARSEN, ESPER S., 3d, 7108 Radnor Road, Bethesda 14, Maryland.
- LASZKIEWICZ, ANTONI, Ulica Chmielna 34, Warsaw, Poland.
- *LAUSEN, CARL, c/o Texas A. & M. College, Dept. of Geology, College Station, Texas.
- LEACH, FRANCIS J., Lordsburg, New Mexico.
- *LEE, HARLEY C., Basic Refractories, Inc., 845 Hanna Bldg., Cleveland 15, Ohio.
- *LEE, O. IVAN, 2684 Boulevard, Jersey City 6, New Jersey.
- LEFOND, STANLEY, Box 6486, University Station, Baton Rouge, Louisiana.
- LEHN, JOSEPH W., 711 Varnum Street, N.W., Washington 11, D. C.
- LEITH, CARLTON J., Department of Geology, Indiana University, Bloomington, Indiana.
- LEMKE, RICHARD W., 5930 13th Place, N.W., Washington 11, D. C.
- *LEMMLEIN, G. G., Inst. of Crystallography, Academy of Science, Moscow, U.S.S.R.
- *LEMMON, DWIGHT M., U. S. Geological Survey, Washington 25, D. C.
- LEONARD, BENJAMIN F., III, c/o Dept. of Geology, Princeton University, Princeton, New Jersey.
- LETORT, YVES, 16, Rue Lalo, 16, Paris (8°), France.
- LEVIN, S. BENEDICT, 50 Crest Drive, Little Silver, New Jersey.
- LEWIS, W. SCOTT, 2500 N. Beachwood Drive, Hollywood 28, California.
- LINCOLN, EARLE R., Holberg, British Columbia, Canada.
- *LINDBERG, MRS. MARIE LOUISE, U. S. Geological Survey, Washington 25, D. C.
- LINDE, HENRY E., P.O. Box #130, Austin 2, Texas.
- LINVILLE, P. E., 2017 Taft Avenue, Hollywood 28, California.
- LO BIONDO, DONLON, Tiger, Arizona.
- LOHSE, R. A., Route #1, Box 55, Woodburn, Oregon.
- *LONSDALE, JOHN T., Bureau of Economic Geology, University of Texas, Box B, University Station, Austin 12, Texas.
- LONSDALE, KATHLEEN, University College, Gower Street, London, W. C. 1, England.
- *LOPEZ, VICTOR M., Servicio Tecnico de Geologia, Ministerio de Fomento, Caracas, Venezuela.
- *LOUDERBACK, GEORGE D., Dept. of Mineralogy, University of California, Berkeley 4, California.
- *LOVERING, THOMAS S., Dept. of Geology, University of Arizona, Tucson, Arizona.

- LOWE, KURT E., 196 Rockaway Parkway, Brooklyn 12, New York.
- LOWE, W. ROSS, Sudbury Assay Office, 256 Oak Street, Sudbury, Ontario, Canada.
- LOWENSTEIN, WALTER, Ruo Morro Verde, 16, Sao Paulo, Brazil, S. A.
- LUKESH, JOSEPH STEVENS, 516 Riverside Avenue, Scotia, New York.
- LYONS, ERWIN J., Wisconsin Institute of Technology, Platteville, Wisconsin.
- LYONS, JOHN B., 19 South Park Street, Hanover, New Hampshire.
- *MACDONALD, GORDON A., U. S. Geological Survey, Hawaiian Volcano Observatory, Hawaii National Park, T. H.
- MACKAY, RALPH E., 2923 East Harrison Street, Seattle 2, Washington.
- MACKENZIE, G. S., Dept. of Geology, University of New Brunswick, Fredericton, N.B., Canada.
- MACLACHLEN, J. C., Dept. of Geology, Princeton University, Princeton, New Jersey.
- MAGRI, R. J., JR., Corhart Refractories Co., 1600 W. Lee Street, Louisville 10, Kentucky.
- *MARBLE, JOHN P., 3221 Macomb Street, N.W., Washington 8, D. C.
- MARCIN, EDWARD J., 10314 97th Avenue, Ozone Park, New York.
- MARINOS, GEORGE, Aminandrou 31 Koukaki, Athens, Greece.
- MARKMAN, HARVEY C., Colorado Museum of Natural History, City Park, Denver 6, Colorado.
- MARSHALL, C. EDMUND, Department of Soils, College of Agriculture, University of Missouri, Columbia, Missouri.
- *MARSHALL, E. M., Bethel, Connecticut.
- *MARTENS, JAMES H. C., Bureau of Mineral Research, Rutgers University, New Brunswick, New Jersey.
- MARTIN, E. B., Westbury, Long Island, New York.
- *MASON, BRIAN H., Dept. of Geology, Indiana University, Bloomington, Indiana.
- MASON, VINCENT I., 154 Beaumont Ave., Newtonville 60, Massachusetts.
- MATEER, W. D., Geology Dept., Colorado School of Mines, Golden, Colorado.
- MATHEWSON, HARRIS D., Box 582, Berkeley 1, California.
- MATTHEWS, FRED W., Canadian Industries, Ltd., Central Research Laboratory, McMasterville, Quebec, Canada.
- MATVEEV, K. K., Ul. Lenina, D. 52, kv. 253, Sverklvovsk, U.S.S.R.
- MAUGUIN, CHARLES, Laboratoire de Mineralogie de la Sorbonne 1, Rue Victor-Cousin, Paris 5, France.
- MAURICE, CHARLES S., 215 Cameron Avenue, Chapel Hill, North Carolina.
- MAWBY, M. A., Collins House, 350 Collins Street, Melbourne, Victoria, Australia.
- *MAYNARD, JAMES E., Dept. of Mineralogy, Syracuse University, Syracuse, New York.
- *MCCAUGHEY, WILLIAM J., Lord Hall, Ohio State University, Columbus, Ohio.
- *MCCONNELL, DUNCAN, Gulf Research & Development Co., P.O. Drawer 2038, Pittsburgh, Pennsylvania.
- MCREEERY, G. L., Ohio Brass Co., Box 11, Barberton, Ohio.
- MCINTOSH, ALEX O., Chemistry Dept., The University, Glasgow W. 2, Scotland.
- *MCKINSTRY, HUGH E., Rotch Building, Cambridge 38, Massachusetts.
- *MCLAUGHLIN, DONALD H., c/o 100 Bush Street, 26th Floor, San Francisco 4, California.
- MCLELLAN, ROY D., American Smelting & Refining Co., Barber, New Jersey.
- MCLEOD, MRS. EDITH, 413 High Street, Klamath Falls, Oregon.
- *MCVAY, THOMAS N., School of Chemistry, University of Alabama, University, Alabama.
- *MEEN, V. BEN, Dept. of Geological Sciences, University of Toronto, Toronto 5, Canada.
- MELLIS, OTTO, Mineralogiska Institutet, Uppsala, Sweden.
- MENCHER, ELY, c/o Socony-Vacuum Oil Company of Venezuela, Apartado 246, Caracas, Venezuela.

- MERGNER, JOHN L., 5519 Nevada Avenue, N.W., Washington, D. C.
- *MERRITT, CLIFFORD A., University of Oklahoma, Norman, Oklahoma.
- MERRITT, PHILLIP, Columbia University Club, 4 West 43rd Street, New York, N. Y.
- *MERTIE, JOHN B., JR., U. S. Geological Survey, Washington 25, D. C.
- *MERWIN, HERBERT E., Geophysical Laboratory, 2801 Upton Street, N.W., Washington 8, D. C.
- MEYER, CHARLES, Box 597, Butte, Montana.
- MEYERS, T. R., Dept. of Geology, University of New Hampshire, Durham, New Hampshire.
- MIAN, IRSHAD AABI, Daska P.O., Distt Sialkot, West Punjab, Pakistan.
- MICHELL BAWDEN, F. C., c/o Geology Dept., New Consolidated Goldfields, Box 1167, Johannesburg, South Africa.
- MICHENFELDER, F., 210 46th Street, Union City, New Jersey.
- MIELLENZ, RICHARD C., Bureau of Reclamation, Customhouse, Denver 2, Colorado.
- MIKAMI, HARRY M., E. J. Lavino & Co., Box 29, Norristown, Pennsylvania.
- MIKHEEV, V. I., Pl. Ostrovskogo, Dom. 9 kv. 41, Leningrad 11, U.S.S.R.
- MILLER, F. STUART, 50 South Remington Road, Bexley, Columbus, Ohio.
- MILLER, ROSWELL, 3rd, 9 Campbellton Circle, Princeton, New Jersey.
- *MILLER, WILLIAM J., 436 West Willow Street, Stockton 19, California.
- MILNER, ARTHUR H., 3954 N. Capitol Avenue, Indianapolis 8, Indiana.
- *MILTON, CHARLES, U. S. Geological Survey, Washington 25, D. C.
- MINER, EUGENE D., Box 5595, College Station, Texas.
- *MISER, HUGH D., U. S. Geological Survey, Washington 25, D. C.
- *MONEYMAKER, BERLEN C., c/o T.V.A. Geologic Div., 620 Union Bldg., Knoxville, Tennessee.
- *MONTGOMERY, ARTHUR, 277 Park Avenue, New York City.
- *MOORE, ELWOOD S., University of Toronto, Toronto 5, Canada.
- MOORE, JOHN J., 1444 Dorchester Avenue, Dorchester, Massachusetts.
- MOORE, KENNETH P., 533 South Grant, Casper, Wyoming.
- MORGAN, LEONARD A., 216 Jones Avenue, Burlington, New Jersey.
- MORRIELLO, PATRICK, 85 West 21st Street, Bayonne, New Jersey.
- *MORRIS, FREDERICK K., Dept. of Geology, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.
- MORRISON, BERT C., 4930 Cutting Blvd., Apt. 1, Richmond, California.
- MORTOLA, DRA. EDELMIRE, Rodriguez Pena 1719, Buenos Aires, Argentina.
- MOYD, LOUIS, Minerals, Ltd., Bancroft, Ontario, Canada.
- MROSE, MARY E., 546 Newbury Street, Boston, Massachusetts.
- MULLNER, HENRY C., 79 Ackerman Avenue, Clifton, New Jersey.
- *MURATA, K. J., U. S. Geological Survey, Washington 25, D. C.
- *MURDOCH, JOSEPH, University of California at Los Angeles, 24, California.
- MURPHY, RICHARD, Newmont Mining Corporation of Canada, Room 1721, 5 King Street West, Toronto, Canada.
- MURRAY, ALBERT N., Dept. of Geology, University of Tulsa, Tulsa 4, Oklahoma.
- MYERS, ALFRED T., 6914 Oakridge Road, College Heights, Hyattsville, Maryland.
- *MYERS, WILLIAM M., School of Mineral Industries, Pennsylvania State College, State College, Pennsylvania.
- *NAGELSCHMIDT, GUNTER, 52 Turo Road, St. Austell, Cornwall, England.
- NALLE, PETER B., Bethlehem Pike, Whitmarsh, Pennsylvania.
- NEIMAN, ROBERT, 505 E. Chestnut Street, Louisville 2, Kentucky.
- *NEL, HANS JURIE, Geological Survey, Pretoria, Union of South Africa.

- NELSON, HARRY E., 1020 West Silver Street, Butte, Montana.
NEUERBURG, GEORGE J., 12615 Chandler Blvd., North Hollywood, California.
NEWBY, CHESTER A., 1927 Hennepin Avenue, Minneapolis 5, Minnesota.
*NEWHOUSE, WALTER H., Department of Geology, University of Chicago, Chicago, Illinois.
NEWMAN, GEORGE H., c/o Marsman & Co., Marsman Building, Boston Street, Manila, Philippine Islands.
NICHOLS, JOSEPH B., 2830 D Street, Sacramento 16, California.
NIESET, CARL F., St. Joseph College, Collegeville, Indiana.
NIKOLAEV, V. A., Srednii pr., d. 11 kv. 39, Leningrad 53, U.S.S.R.
NILES, GLENN H., P.O. Box 4, Ridgewood, New Jersey.
NISSON, WILLIAM H., 815 D Street, Petaluma, California.
NIXON, H. L., Rothamsted Experimental Station, Harpenden Herts, England.
*NOBLE, JAMES A., California Institute of Technology, Pasadena 4, California.
*NOLAN, THOMAS B., U. S. Geological Survey, Washington 25, D. C.
NORTHUP, M. ALLEN, 10 Godet Place, Morristown, N. J.
NORTON, JAMES J., Box 71, Custer, South Dakota.
NOWACKI, W., H. Sahlistr. 6, Min. Inst. Univ., Bern, Switzerland.
*NUFFIELD, EDWARD W., Dept. of Geological Sciences, University of Toronto, Toronto 5, Canada.
NUTTING, P. G., 3216 Oliver Street, N.W., Washington, D. C.
NYGREEN, PAUL W., Delta Tau Delta, 4524 19th Street, N.W., Seattle 5, Washington.
- OKE, WILLIAM C., 9115 South Harvard Boulevard, Los Angeles 44, California.
O'LEARY, THOMAS S., 2240 Hyde Street, San Francisco, California.
O'LEARY, W. J., 108 Cahill Lane, Oake Ridge, Tennessee.
OLMSTEAD, IRVINE, 264½ Arlington Avenue, Jersey City, New Jersey.
OLSON, J. C., U. S. Geological Survey, Washington 25, D. C.
*ORCEL, JEAN, Museum d'Histoire Naturelle, 61 Rue de Buffon, Paris V, France.
ORTEGA, FRANCISCO BARROSO, Lab. No. 2 de Mineralogia, Facultad de Ciencias, Universidad de la Habana, La Habana, Cuba.
*OSBORN, ELBURT FRANKLIN, Dept. of Earth Sciences, School of Mineral Industries, Pennsylvania State College, State College, Pennsylvania.
OTERSEN, MRS. LILLIAN M., 16 Grove Place, Prospect Beach, West Haven, Connecticut.
OVER, EDWIN, YMCA, Colorado Springs, Colorado.
- *PABST, ADOLF, Dept. of Geology, University of California, Berkeley 4, California.
PACLT, JIRI, Kamenicka 5; Praha VII, Czechoslovakia.
PAGE, JAMES J., RFD 2, Pike, New Hampshire.
*PAGE, LINCOLN R., P.O. Box 71, Custer, South Dakota.
*PALACHE, CHARLES, 106 Appleton Street, Cambridge 38, Massachusetts.
*PARK, CHARLES FREDERICK, JR., Department of Geology, Stanford University, California.
*PARKER, ROBERT L., Technische Hochschule, Sonneggstr. 5, Zürich 6, Switzerland.
PARNAU, JOHN L., 1342 North Lincoln Street, Stockton, California.
*PARRISH, WILLIAM, Philips Laboratories, Inc., Irvington-on-Hudson, New York.
*PARSONS, ARTHUR L., Royal Ontario Museum of Mineralogy, 100 Queen's Park, Toronto 5, Ontario, Canada.
*PARSONS, WILLARD HALL, Department of Geology, Wayne University, Detroit 1, Michigan.

- *PATTERSON, A. L., Bryn Mawr College, Bryn Mawr, Pennsylvania.
 PATTERSON, C. MEADE, P.O. Drawer 2038, Pittsburgh 30, Pennsylvania.
- *PEACOCK, MARTIN A., Dept. of Geological Sciences, University of Toronto, Toronto 5, Canada.
- PEARCE, D. W., 1211 Marshall, Richland, Washington.
- PEARL, RICHARD M., Colorado College, Colorado Springs, Colorado.
- *PECORA, WILLIAM T., U. S. Geological Survey, Washington 25, D. C.
- *PEGAU, ARTHUR A., 1808 Winston Avenue, Charlottesville, Virginia.
- PELTO, CHESTER R., MRD Laboratory, Corps of Engineers, 18th & Howard Sts., Omaha 2, Nebraska.
- PENDLETON, NORMAN H., 11 Pryce Street, Santa Cruz, California.
- *PEOPLES, JOE WEBB, Dept. of Geology, Wesleyan University, Middletown, Connecticut.
- *PEPINSKY, RAYMOND, Department of Physics, Alabama Polytechnic Institute, Auburn, Alabama.
- PERUSEK, CYRIL J., The Texas Company, Midland, Texas.
- PEQUERA, RUBEN E., Parque Hidalgo No. 14, Pachuca, Hidalgo, Mexico.
- PETERSON, NELS P., Box 1211, Globe, Arizona.
- PETRETIC, GEORGE J., U. S. Geological Survey, Geologic Branch, Box 2746, Lakewood Branch, Denver 15, Colorado.
- PHAIR, GEORGE, Department of Geology, Princeton University, Princeton, New Jersey.
- *PHEMISTER, T. C., Dept. of Geology and Mineralogy, Marischal College, University of Aberdeen, Aberdeen, Scotland.
- PHILBROOK, MRS. P. M., P.O. Box 184, Sacramento, California.
- PIERCE, ALBERT C., 470 Gainesboro Road, Drexel Hill, Pennsylvania.
- PITHA, CARL A., 182-18 Wexford Terrace, Jamaica 3, New York.
- PIZARRO, CARLOS JILES, Casilla 23, Ocalte, Chile, S. A.
- POCOVI, ANTONIO, Rivadavia 3567, Santa Fe, Argentina.
- POIRE, INNA V., U. S. Geological Survey, FWA Building, Room 1228, Washington 25, D. C.
- POLKANOV, A. A., Vasiljevsk Ostrov, 5 Ja Linija D. 20, kv. 3, Leningrad, S. S. S. R.
- POOLE, S. W., 1011 16th Street, N.W., Canton 3, Ohio.
- POPOV, S. P., Ul. Majakovskogo, D. 22, kv. 6, Kharkov, U.S.S.R.
- POSTEL, A. WILLIAMS, Dept. of Geology, Bryn Mawr College, Bryn Mawr, Pennsylvania.
- *POUGH, FREDERICK H., American Museum of Natural History, 77th Street and Central Park West, New York 24, New York.
- PRATHER, ROBERT W., Dept. of Physics, Oregon State College, Corvallis, Oregon.
- PRATT, WALDEN P., 65 Evans Street, Williamsville, Buffalo 21, New York.
- PRESGRAVE, CYRIL, Box 4372, Chestnut Hill, Philadelphia, Pennsylvania.
- PRIBIL, VICTOR, c/o New York Art Iron Works Co., 47-18 37th Street, Long Island City #1, New York.
- PRIDER, REX T., University of Western Australia, Dept. of Geology, Nedlands, Western Australia.
- PRIEN, EDWIN L., 194 Waban Avenue, Waban 68, Massachusetts.
- PRUCHA, JOHN JAMES, Dept. of Geology, Rutgers University, New Brunswick, New Jersey.
- PRUDICH, FRANK, Powellton, Box 115, West Virginia.
- *QUENSEL, PERCY D., Stockholms Högskola, Stockholm, Sweden.
- QUEST, H. J. M., Box 54, Klerksdorp, Transvaal, South Africa.
- *QUINN, ALONZO W., Dept. of Geology, Brown University, Providence 12, Rhode Island.

- *RABBITT, JOHN C., U. S. Geological Survey, Washington 25, D. C.
RAHKO, HANNES, Box 205, Vader, Washington.
RAMBERG, HANS, Dept. of Geology, University of Chicago, Chicago 37, Illinois.
- *RAMSDELL, LEWIS S., Mineralogical Laboratory, University of Michigan, Ann Arbor, Michigan.
- *RANKAMA, KALervo, Dept. of Geology, University of Chicago, Chicago 37, Illinois.
REED, FRANK S., 3118 Rittenhouse Street, N.W., Washington, D. C.
REEVES, AUGUSTUS, Clayton, Utah.
- *REINHARD, MAX, Mineralogical Institute, University of Basel, Basel, Switzerland.
REYES, JORGE MUNOZ, Apartado 267, La Paz, Bolivia.
- RICE, H. M., Chemistry Division, Central Experimental Farm, Ottawa, Canada.
- *RICHMOND, WALLACE E., JR., 234 Lawnside Avenue, Collingswood, New Jersey.
RIDGE, JOHN D., Lemont, Centre County, Pennsylvania.
- *RIES, HEINRICH, 401 Thurston Avenue, Ithaca, New York.
RINN, HAROLD W., 2917 Braley Court, Midland, Michigan.
RISCH, May, 139 West 91st Street, New York, New York.
RITCHIE, A. J., 2474 Hudson Blvd., Jersey City 4, New Jersey.
RITCHIE, EVERETT J., c/o Eagle-Picher Company, Research Laboratories, Joplin, Missouri.
- ROBERTSON, E. C., c/o Dept. of Geology, Harvard University, Cambridge 38, Massachusetts.
- ROBERTSON, FORBES, Dept. of Geology, Montana School of Mines, Butte, Montana.
- ROBINSON, G. D., Section of General Geology, U. S. Geological Survey, Denver Federal Center, Denver 14, Colorado.
- RODEKOH, W. J., 25 Elgin Street, Alhambra, California.
- ROEDDER, EDWIN W., 70 Haven Avenue, Apt. 4H, New York 32, N. Y.
- *ROGERS, AUSTIN F., Stanford University, California.
- ROLLINS, ROSS, 79 Cypress Street, Brookline, Massachusetts.
- ROLSHAUSEN, F. W., P.O. Box 2180, Houston 1, Texas.
- ROONEY, JOHN T., Box 358, Buffalo, New York.
- ROSENFELD, JOHN L., 65 Rutland Street, Watertown 72, Massachusetts.
- *ROSENHOLTZ, JOSEPH L., Rensselaer Polytechnic Institute, Troy, New York.
ROSENKRANS, R. R., 3439 Broadmoor, Shreveport 56, Louisiana.
- ROSEYEAR, F. B., Chemical Division, Proctor & Gamble Co., Cincinnati 17, Ohio.
- *ROSS, CLARENCE S., U. S. Geological Survey, Washington 25, D. C.
ROSS, MRS. KIP, Broadmoor #305, 3601 Connecticut Avenue, N.W., Washington 8, D.C.
- *ROWLAND, RICHARDS A., Shell Oil Company, P.O. Box 2099, Houston 1, Texas.
ROWLEY, ELMER B. 214 Ridge Street, Glens Falls, New York.
- ROYAL, H. F., Champion Spark Plug Co., 8525 Butler Avenue, Detroit 11, Michigan.
- ROYER, LOUIS, Laboratoire de Min. et Crist. de l'Université, Algiers, Algeria.
- RUNNER, DELMAR G., 4606 47th Street, N.W., Washington 16, D. C.
- *RUNNER, JOSEPH J., Geology Building, University of Iowa, Iowa City, Iowa.
- *RUTHERFORD, RALPH L., Dept. of Geology, University of Alberta, Edmonton, Alberta, Canada.
- SACHS, WALTER P., 254 Bloomfield Avenue, Caldwell, New Jersey.
- SAFFORD, ARTHUR T., JR., 333 Homestead Avenue, Hartford, Connecticut.
- SAHLIN, BERGSING. CARL-INGEMAR, Villastigen 1, Kiruna, Sweden.
- SALETET, LOUIS, University of Dayton, Dayton 9, Ohio.
- *SAMPSON, EDWARD, Princeton University, Princeton, New Jersey.
SAMPLER, E. L., 49 West 45th Street, New York 19, New York.

- SANDERS, K. W., Hindenburgring 35, 20b Bad Harzburg, Land Braunschweig, Germany, British Zone.
- SAN MARTIN Y SAENZ, RENÉ, Laboratorio de Mineralogia No. 1, Facultad de Ciencias, Universidad de la Habana, La Habana, Cuba.
- SARARITSKIJ, A. N., Knizhnyj Otdel Akad. Nauk, ulica Kropotkina 16, Moscow 34, U.S.S.R.
- SAYLOR, PAULINE A., 2444 E. Bonita Avenue, Covina, California.
- *SCHAIRER, JOHN F., Geophysical Laboratory, 2801 Upton Street, N.W., Washington 8, D. C.
- *SCHALLER, WALDEMAR T., U. S. Geological Survey, Washington 25, D. C.
- SCHIED, VERNON E., University of Idaho, Moscow, Idaho.
- SCHLECHT, WILLIAM G., U. S. Geological Survey, Washington 25, D. C.
- SCHLOCKER, J., U. S. Geological Survey, 105 Old Mint Bldg., San Francisco, California.
- *SCHMITT, HARRISON A., Box 572, Silver City, New Mexico.
- *SCHNEIDER, HYRUM, University of Utah, Salt Lake City 1, Utah.
- SCHNEIDER, PHILIP E., Antioch College, Yellow Springs, Ohio.
- SCHOENLAUB, R. A., Sylvester and Co., Terminal Tower, Cleveland 13, Ohio.
- *SCHOEP, ALFRED, 97 Baudeloo Street, Ghent, Belgium.
- SCHORTMANN, RAYMOND E., 306 Main Street, Easthampton, Massachusetts.
- SCHRAUT, JOSEPH A., JR., 4125 Fillmore, St. Louis 16, Missouri.
- SCHREIBER, JOSEPH F., JR., 5505 Lothian Road, Baltimore 12, Maryland.
- SCHWARTZ, B., 1884 Monroe Avenue, Bronx, New York 57, N. Y.
- *SCHWARTZ, GEORGE M., Dept. of Geology, University of Minnesota, Minneapolis 14, Minnesota.
- SCOTT, DONALD W., 505 King Avenue, Columbus 1, Ohio.
- SCOTT, HORACE A., 327 East Pine Street, Santa Ana, California.
- SEGLER, CURT G., 284 East 16th Street, Brooklyn 26, New York.
- SEIFERT, H., Mineralogical-Petrographic Institute, Westphalian Land University, (21a) Munster i.W., Germany.
- *SHAND, S. JAMES, Department of Geology, Columbia University, New York 27, N. Y.
- SHAFRANOASKIJ, I. I., V. O. Tuchkov per., Dom. 11 kv. 31, Leningrad, U.S.S.R.
- SHAININ, VINCENT E., Dept. of Civil Engineering, University of Maine, Orono, Maine.
- *SHAUB, BENJAMIN M., 159 Elm Street, Northampton, Massachusetts.
- SHEHEEN, ALEXANDER T., 80 Elm Street, Hornell, New York.
- SHERMAN, WALTER C., 27 Doro Place, Rumford 16, Rhode Island.
- SHIPLEY, ROBERT M., Gemological Institute of America, 541 S. Alexandria Ave., Los Angeles 5, California.
- SHIPTON, W. D., Department of Geology, Washington University, St. Louis 5, Missouri.
- *SHORT, MAX N., Dept. of Geology, University of Arizona, Tucson, Arizona.
- SHORT, NICHOLAS M., 6621 University Drive, University City 5, Missouri.
- SHORTLE, WALTER C., 65 Lincoln Street, Laconia, New Hampshire.
- SIDWELL, RAYMOND, Dept. of Geology, Texas Technical College, Lubbock, Texas.
- SIEGRIST, MARIE, 1431 Iris Street, N.W., Washington 12, D. C.
- SIEVERS, D. C., 1626 Woodside Avenue, Kingsport, Tennessee.
- SILBERSTEIN, M. L., 1607 Francis St., Houston 4, Texas.
- SILVER, LEON T., Division of Geological Sciences, California Institute of Technology, Pasadena 4, California.
- SIMCOCK, J. H., Cranford, Lovatt Avenue, Milehouse, Newcastle, Staffordshire, England.
- SIMONS, FRANK S., U. S. Geological Survey, Paseo de la Reforma 64, Mexico D. F., Mexico.
- SIMS, A. E., Box 192, Natchez, Mississippi.

- *SINGEWALD, QUENTIN D., U. S. Geological Survey, Washington 25, D. C.
 SKEA, E. M., P.O. Box 46, Pilgrims Rest, Transvaal, South Africa.
 SKINNER, JOHN W., JR., Box 1267, College Station, Texas.
 SLAVIN, MORRIS, 4610 Knox Road, College Park, Maryland.
- *SLAWSON, CHESTER B., Mineralogical Laboratory, University of Michigan, Ann Arbor, Michigan.
- SMEDES, HARRY W., Dept. of Geology, University of Washington, Seattle 5, Washington.
 SMITH, C. B., Philippi, West Virginia.
 SMITH, D. T., Rensselaer Polytechnic Institute, Troy, New York.
 SMITH, EDWARD S. C., Geology Laboratory, Union College, Schenectady 8, New York.
 SMITH, HAROLD M., 2233 N. 17th Avenue, Phoenix, Arizona.
 SMITH, O. C., 5157 Santa Ana Street, Bell, California.
 SMITH, PETER A., Box 183, Highland Mills, New York.
 SMITH, ROBERT L., Fair Oaks, California.
- *SMITH, WARD C., 99 El Camino Real, Berkeley 5, California.
- *SNELGROVE, ALFRED K., Dept. of Geology, Michigan College of Mining and Technology, Houghton, Michigan.
- SNOW, ROLAND B., Research Laboratory, U. S. Steel Corporation, Kearny, New Jersey.
 SNYDER, FRANK G., Dept. of Geology, University of Tennessee, Knoxville, Tennessee.
 SOTOMAYOR, EUGENIO, 6a Regina 147, Mexico, D. F., Mexico.
 SOWERS, GEORGE M., Dept. of Geology, Washington University, St. Louis 5, Missouri.
- *SPENCE, HUGH S., Canada Department of Mines, Ottawa, Canada.
- SPERRY, ARTHUR B., Dept. of Geology, Kansas State College of Agriculture and Applied Science, Manhattan, Kansas.
- SPIROFF, KIRIL, Houghton, Michigan.
- SPRINGER, W. M., Bristol-Myers Co., 225 Long Avenue, Hillside, New Jersey.
- SPROAT, IRA E., Gorham Avenue, Westport, Connecticut.
- SRIKANTAN, B., Geological Survey of India, Southern Circle, Mylapore Madras 4, India.
- STAATZ, MORTIMER H., 239 West 105th Street, New York 25, N. Y.
 STADNICHENKO, TAISIA, U. S. Geological Survey, Washington 25, D. C.
- *STANTON, GILMAN S., 245 West 104th Street, New York 25, N. Y.
 STANWOOD, CREIGHTON B., 12 Kilburn Road, Belmont 78, Massachusetts.
- *STAPLES, LLOYD W., Dept. of Geology, University of Oregon, Eugene, Oregon.
- *STARK, JOHN T., Dept. of Geology, Northwestern University, Evanston, Illinois.
- STEAD, FRANK, U. S. Geological Survey, Washington 25, D. C.
- STEARNS, RICHARD S., JR., Courtland, Arizona.
- STEEDMAN, R. D., 17 Saville Row, Newcastle-on-Tyne, England.
- STEEL, GEO. E., 37 Mason Blvd., Toronto, Ontario, Canada.
- STEEN, CHARLES A., 3803 Arbor Street, Houston 4, Texas.
- STEINOCHEK, VLADIMIR, 721 Neratovicka, Prague VIII Kobylisy, Czechoslovakia.
- STEPHANO, C. S., 1016 Walnut Street, Philadelphia 7, Pennsylvania.
- STEPHENS, HAL G., Box 71, Custer, South Dakota.
- STEVENS, D. H., 2557 Casitas Avenue, Altadena, California.
- *STEVENS, ROLLIN E., U. S. Geological Survey, Washington 25, D. C.
- *STEVENSON, JOHN S., Dept. of Mines, Victoria, British Columbia, Canada.
 STEVENSON, MRS. JOHN S., 1340 Richardson Street, Victoria, British Columbia.
- *STEWART, DUNCAN, Dept. of Geology, Carleton College, Northfield, Minnesota.
- STILWELL, STEPHEN N., 315 Empire Building, Knoxville, Tennessee.
- STIPP, RICHARD A., 1336 East 4th Street, Tucson, Arizona.
- STIVERS, GLEN H., Box 581, Tustin, California.
- STOBBE, HELEN, Baldwin House, Smith College, Northampton, Massachusetts.

- STOFFERAN, E., 150 Davis Avenue, Bronx 61, New York.
- *STOIBER, RICHARD E., McKenna Road, Norwich, Vermont.
- STOUT, JEFF, Francitas, Texas.
- *STOW, MARCELLUS H., 405 Massie Street, Lexington, Virginia.
- STRAND, JESSE R., Box 521, College Station, Pullman, Washington.
- *STRINGHAM, BRONSON F., University of Utah, Salt Lake City, Utah.
- *STROCK, LESTER W., 21 Madison Avenue, Saratoga Springs, New York.
- STRUNZ, H., Weiden/Opf., Hermann Fuldstrasse 12, Bavaria, U. S. Zone.
- *STUCKEY, JASPER L., 1911 Sunset Drive, Raleigh, North Carolina.
- SULLIVAN, DOUGLAS W., Canadian Refractories Ltd., Kilmar, Quebec, Canada.
- SVERDZIK, A., Robinson and Sverdzik, Inc., 610 Fifth Avenue, New York, N. Y.
- SWANSON, VERNON E., Geology Department, Upsala College, East Orange, New Jersey.
- SWINNERTON, A. C., 145 West Limestone Street, Yellow Springs, Ohio.
- *SWITZER, GEORGE, U. S. National Museum, Washington 25, D. C.
- SZADECZKY-KARDOSS, ELEMÉR, Inst. of Mineralogy and Geology, Sopron University, Sopron, Hungary.
- *TABER, STEPHEN, 1518 Deans Lane, Columbia 5, South Carolina.
- TAKATSUI, FUMIO, USVA Veterans Hospital, Walla Walla, Washington.
- TANGIER SMITH, W. S., 1231 Hoover Street, Menlo Park, California.
- TATGE, ELEANOR, 5811 14th Street, N.W., Washington, D. C.
- TAUBER, J. A. P.O. Box 29, Norristown, Pennsylvania.
- *TAVORA, ELYSIÁRIO, National Faculty of Philosophy, University of Brazil, Rio de Janeiro, Brazil.
- TAYLOR, EDWARD D., Major, Quarters 31, Fort Belvoir, Virginia.
- TAYLOR, JAMES A., 38 Douglas Road, Glen Ridge, New Jersey.
- TAYLOR, RALPH E., 315 East Maple Street, Maple Ridge Park, New Orleans 20, Louisiana.
- TAYLOR, W. H., The Cavendish Laboratory, Crystallographic Section, Free School Lane, Cambridge, England.
- *THIBAUT, N. W., Norton Company, Worcester, Massachusetts.
- THOMAS, Pfc. EDWIN D. (653490), USMC, Hdq. Co., Hdqs. & Service, BN, 1st Prov. Marine Brigade, c/FPO, San Francisco, California.
- THOMAS, W. HERSEY, 145 East Gorgas Lane, Mt. Airy, Philadelphia, Pennsylvania.
- THOMPSON, CLYDE L., c/o Harbison-Walker Refractories Co., Hays Laboratory, Pittsburgh 7, Pennsylvania.
- THOMPSON, ROBERT M., Dept. of Geology & Geography, University of British Columbia, Vancouver, B. C., Canada.
- THOMSON, ROBERT, Box 913, Cobalt, Ontario, Canada.
- THURSTON, WILLIAM R., Box 2858, Lakewood Branch, Denver 15, Colorado.
- TIFFANY, THOMAS E., 14-24 Sixth Avenue, S.W., Aberdeen, South Dakota.
- *TOLMAN, CARL, Dept. of Geology, Washington University, St. Louis 5, Missouri.
- TOMLINSON, W. HAROLD, 260 North Rolling Road, Springfield, Pennsylvania.
- *TOOTHAKER, CHARLES R., Commercial Museum, 24th and Spruce Streets, Philadelphia 4, Pennsylvania.
- TOWNSEND, ROLAND C., U. S. Geological Survey, Geologic Branch, Denver Federal Center, Denver 14, Colorado.
- TRAINER, DAVID W., JR., 48 Payne Street, Hamilton, New York.
- TRAINER, J. N., 233 East 62d Street, New York, N. Y.
- TRAUTZ, OTTO R., Dept. of Chemistry, New York University, College of Dentistry, 209 East 23d Street, New York 10, N. Y.
- TREFETHEN, JOSEPH M., Fernald Hall, University of Maine, Orono, Maine.

- TREMBLAY, ABBE J. A., Seminaire de Chicoutimi, Comte de Chicoutimi, P.Q., Canada.
- TRIMBLE, CLINTON E., 3796 Degnan Boulevard, Los Angeles, California.
- TRUDELL, HARRY W., 303 Highland Avenue, Abington, Pennsylvania.
- *TUNELL, GEORGE, 801 Toyopa Drive, Pacific Palisades, California.
- TURNEAURE, F. S., 1905 E. Stadium Drive, Ann Arbor, Michigan.
- TURNER, FRANCIS J., Geology Dept., University of California, Berkeley 4, California.
- TURNER, L. R., Masonite Corporation, Laurel, Mississippi.
- TUROBINSKI, T. J., 1965 East 83d Street, Cleveland, Ohio.
- TUTHILL, ISABEL H., Rocky Point, Long Island, New York.
- TWENHOFEL, WILLIAM S., U. S. Geological Survey, Box 2659, Juneau, Alaska.
- TWETO, OGDEN, U. S. Geological Survey, 230 New Custom House, Denver 2, Colorado.
- UKLONSKIJ, A. S., Ul. K. Marksa d. 59, kv. 8, Tashkent, U.S.S.R.
- VALENTINE, GRANT M., Rt. 6, Box 576, Olympia, Washington.
- VAN ALSTINE, E., Alaskan Branch, U. S. Geological Survey, Washington 25, D. C.
- VANCE, LOUIS W., 1002 Palm Avenue, South Pasadena, California.
- VAN COTT, H. CORBIN, 40 Fulton Street, Corning, New York.
- VANDEREIKE, PAUL, Rt. 5, Box 177, Bakersfield, California.
- VAN DER LEUR, R., P.O. Box 2034, Hartford 1, Connecticut.
- VAN HORN, EARL C., 180 Coxe Avenue, Asheville, North Carolina.
- VAN HORN, MAURICE H., Research Laboratories, Eastman Kodak Company, Kodak Park, Rochester 4, New York.
- VENUTO, JOSEPH, Geological Museum, Harvard University, Cambridge 38, Massachusetts.
- VERCELLINO, WILTON C., Box 5695, College Station, Texas.
- VERPLANCK, P. B., c/o Whitehall Company, Inc., P.O. Box 502, Keene, New Hampshire.
- VESIGNIE, JEAN PAUL LOUIS, 22 Rue du General Foy, Paris VIII, France.
- VHAY, JOHN STEWART, 707 Peyton Building, Spokane 8, Washington.
- VICKERS, A. ERIC J., Wynnstay, Millfield Road, Whickham, Newcastle-Upon-Tyne, England.
- VIETZKE, FRED W. C., R.F.D. #1, Box 10, Rapid River, Michigan.
- VILIMEK, JOS. R., 2 Palackeho, Bratislava, Czechoslovakia.
- DE VILLIERS, J. E., Geological Survey, Box 401, Pretoria, Union of South Africa.
- *VITALIANO, CHARLES J., Dept. of Geology, Indiana University, Bloomington, Indiana.
- VOLESKY, GUSTAV, Jr., 38 Narodni, Prague 2, Czechoslovakia.
- *VONSEN, M., Petaluma, California.
- VREELAND, FREDERICK K., 36 Magee Avenue, Mill Valley, California.
- WADE, F. ALTON, 300 East Withrow, Oxford, Ohio.
- *WAGER, LAWRENCE R., 24 North Bailey, Durham, England.
- *WAHLSTROM, ERNEST E., Department of Geology, University of Colorado, Boulder, Colorado.
- WALDO, ALLEN W., 1335 North Van Buren, Stockton 19, California.
- *WALDSCHMIDT, WILLIAM A., 1901 W. College, Midland, Texas.
- WALL, MILFORD W., 12 Euston Street, Brookline, Massachusetts.
- *WALLACE, ROBERT C., Queen's University, Kingston, Ontario, Canada.
- WALTON, MATT S., JR., Dept. of Geology, Kirtland Hall, Yale University, New Haven, Connecticut.
- WANDKE, ALFRED D., 20 Simonds Road, Lexington, Massachusetts.
- WARNER, ROBERT E., 2980 Pingree Avenue, Detroit, Michigan.

- WARRACH, HENRY C., P.O. Box 162, Hammond, Indiana.
- WARSHAW, MRS. CHARLOTTE M., U. S. Geological Survey, Washington 25, D. C.
- WASHKEN, EDWARD, 2076 Massachusetts Ave., Cambridge 30, Massachusetts.
- *WASSERSTEIN, BENNO, Geological Survey, Union of South Africa, Pretoria, South Africa.
- *WATANABE, TAKEO, Tokyo Imperial University, Tokyo, Japan.
- *WATERS, AARON C., Box 1738, Stanford University, California.
- *WATSON, EDWARD H., Department of Geology, Bryn Mawr College, Bryn Mawr, Pennsylvania.
- *WATSON, KENNETH DEP., Dept. of Geology & Geography, University of British Columbia Vancouver, B. C., Canada.
- *WAYLAND, RUSSELL G., US/UK Coal Control Group, APO 757, Care Postmaster, New York.
- *WEBB, ROBERT W., Dept. of Physical Science, University of California, Santa Barbara, California.
- WEEKS, CHARLES A., Red Gate Lane, Meredith, New Hampshire.
- WEIDHAAS, ERNEST, 63 Iden Avenue, Pelham Manor, New York.
- WEISS, E. JOSEPH, Lord Hall, Ohio State University, Columbus 10, Ohio.
- WEISSENBORN, A. E., So. 157 Howard, Spokane 8, Washington.
- WELLNITZ, ANNA M., Brooklyn College, Bedford & H. Avenues, Brooklyn 10, New York.
- WELLS, RALPH G., 8720 Mozart Avenue, Chicago 42, Illinois.
- WENDEN, HENRY E., 16 Normandy Road, Woodhaven, Lexington 73, Massachusetts.
- *WEST, CUTLER D., Polaroid Corporation, 718 Main Street, Cambridge 39, Massachusetts.
- *WHERRY, EDGAR T., 27 Oberlin Avenue, Swarthmore, Pennsylvania.
- WHITAKER, GEORGE C., 825 East Schaaf Road, R.D. 3, Brooklyn Station, Cleveland, Ohio.
- WHITE, CHARLES E., Dept. of Chemistry, University of Maryland, College Park, Maryland.
- WHITE, JAMES C. M., 203 Carnegie Place, Pittsburgh 8, Pennsylvania.
- WHITE, J. F., 3564 Anderson, Toledo 6, Ohio.
- WHITE, W. ARTHUR, Illinois Geological Survey, Urbana, Illinois.
- WHITE, W. E., 552 Booth Street, Ottawa, Canada.
- WHITMORE, D. R. E., c/o C. M. & S. Co., Channing, Manitoba, Canada.
- WHITTARD, W. F., Dept. of Geology, The University, Bristol 8, England.
- WICKMAN, FRANS E., Stockholm 50, Sweden.
- WILCOX, RAY E., U. S. Geological Survey, Washington 25, D. C.
- WILKERSON, ALBERT S., Rutgers University, New Brunswick, New Jersey.
- WILLEMS, H. W., 1513 Pacific Avenue, Brackenridge, Pennsylvania.
- WILLIAMS, NORMAN C., 735 8th Ave., Salt Lake City, Utah.
- WILLIS, WILLETT R., 1343 North Nevada Avenue, Colorado Springs, Colorado.
- WILLOW, STEPHEN B., 2 West 47th Street, New York, N. Y.
- *WINCHELL, ALEXANDER N., University Station, Charlottesville, Virginia.
- *WINCHELL, HORACE, Geology Department, Yale University, New Haven, Connecticut.
- WINKLER, H., Mineralogists Institut, (20b) Göttingen, Lotzestr. 16-18, Germany, British Zone.
- WISHART, JAMES S., 56 Hammond Street, Rochester 13, New York.
- WITHROW, JAMES R., 77 16th Avenue, Columbus, Ohio.
- *WOLFE, C. WROE, Department of Geology, Boston University, Boston, Massachusetts.
- WOOD, CLIFFORD H., Box 146, Adelanto, California.
- *WOOD, MRS. ELIZABETH ARMSTRONG, Bell Telephone Laboratories, Murray Hill, New Jersey.

- *WOODFORD, ALFRED O., 443 West 10th Street, Claremont, California.
 WOODHOUSE, C. D., 33 Mimosa Lane, Santa Barbara, California.
 WOODRUFF, T. L., St. Louis Sampling and Testing Works, 3480 Morganford Road, St. Louis 16, Missouri.
 WOODS, ARTHUR E., 1342 W. Beach, Pass Christian, Mississippi.
 WOOLNER, EDWARD S., JR., P.O. Box 4005, Atlanta, Georgia.
 WOYSKI, MRS. M. W. SKILLMAN, Chemistry Dept., University of Wisconsin, Madison, Wisconsin.
 *WRIGHT, FREDERICK E., 2134 Wyoming Avenue, N.W., Washington, D. C.
 WRIGHT, HOWARD W., 9230 Mary Avenue, N.W., Seattle 7, Washington.
- *YAGODA, HERMAN, Industrial Hygiene Research Laboratory, National Institute of Health, Bethesda 14, Maryland.
 YATES, GEORGE W., General Delivery, Ouray, Colorado.
 YOUNG, W. FORD, Apartado 376, Managua, Nicaragua, C. A.
 YOUNG, JOHN A., JR., Sun Oil Company, P.O. Box 1270, McAllen, Texas.
- ZANNARAS, J. P., Box 500, Congress, Arizona.
 ZEIHEN, LESTER G., Care Chile Exploration Co., Chuquicamata (via Antofagasta) Chile, S. A.
 ZEMAN, FREDERIC D., 111 East 88th Street, New York, N. Y.
 ZERFOSS, SAMUEL, Crystal Section, Naval Research Laboratory, Washington 20, D. C.
 ZIMMER, PAUL W., Lyon Mountain, New York.
 ZISSOVITS, LEONARD, Orades Roumania, Str. Belezny A 16, Europe.
 ZODAC, PETER, Box 29, Peekskill, New York.

SUBSCRIBERS

- Academy of Natural Sciences Library, Logan Circle, Philadelphia 3, Pennsylvania.
 Accountable Property Officer, Lib. Section, Reference Office T-2, Headquarters AAF Technical Base, Lab. Area, Bldg. 12, Dayton, Ohio.
 Agricultural and Mechanical College of Texas Library, College Station, Texas.
 Alabama Polytechnic Institute, Library, Auburn, Alabama.
 Allegheny College Library, Meadville, Pennsylvania.
 Aluminum Company of Canada, Ltd., Arvida, Quebec, Canada.
 Amalgamated Brick & Pipe Co., Ltd., Research Dept., Box 539, Auckland, New Zealand.
 American Ambassador, O.I.C. Information Unit, American Embassy, Paris, France.
 American Ceramic Society, Ceramic Abstracts, 2525 N. High Street, Columbus 2, Ohio.
 American Cyanamid Company, Abstract Dept., 1937 West Main Street, Stamford, Connecticut.
 American Museum of Natural History, Library, Central Park West at 79th Street, New York 24, New York.
 American Optical Company, Central Library, Southbridge, Massachusetts.
 American Optical Company, Scientific Instrument Division, Buffalo 15, New York.
 American Potash and Chemical Corporation, Trona, California.
 Amherst College Library, Amherst, Massachusetts.
 Andhra University, Librarian, Waltair, India.
 Andre Bookstore, Havirska 3, Prague 1, Czechoslovakia.
 Antioch College Library, Yellow Springs, Ohio.
 Archiv Upravenie, Glavnyi Pochtamt, Pochtovy Jaschik 752, Moscow, U. S. S. R.

- Arizona State College, The Matthews Library, Tempe, Arizona.
- Arkansas Resources & Development Commission, State Capitol, Little Rock, Arkansas.
- Armour Research Foundation, Illinois Institute of Technology, 35 West 33d Street, Chicago 16, Illinois.
- Armstrong Cork Company, Technical Librarian, Central Technical Laboratory, Lancaster, Pennsylvania.
- Auckland Institute and Museum, Box 27, Newmarket, Auckland, New Zealand.
- Australia, Mines Dept., The Secretary, Treasury Gardens, Melbourne, Victoria, Australia.
- Australian Museum, College Street, Sydney, New South Wales, Australia.
- Bailey Bros. & Swinfen, Ltd., 26/7, Hatton Garden, London E.C. 1, England.
- Bangor Public Library, Bangor, Maine.
- Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio.
- Bausch & Lomb Optical Company, Att: Advertising Manager, 635 St. Paul Street, Rochester, New York.
- Bausch & Lomb Optical Company, Scientific Library, Rochester, New York.
- Bedford College, Regents Park, London, N.W. 1, England.
- Bell Telephone Laboratories, Inc., Technical Library, 463 West Street, New York 14, N. Y.
- Beloit College Library, Beloit, Wisconsin.
- Bergens Museums Bibliotek, Bergen, Norway.
- Bib-ka Ministerstva, Stroimaterialov S.S.S.R., Djakovski Pereulok 4, Moscow, U. S. S. R.
- Biblioteka Akad. Nauk, Ul. Abdulli Tukaeva 1, Tashkent, U. S. S. R.
- Biblioteka Akademii Nauk, Birzhevaja Linija 1, Leningrad, U.S.S.R.
- Biblioteka Uniwersytecka, Torun, Poland.
- Bibl-ka Akademii Nauk, Kommunisticheskaja 10, Baku, U.S.S.R.
- N. V. Boekhandel en Antiquariat, c/o J. L. Beijers, Wed 5, Utrecht, Holland.
- The Bonneville Project, Box 3537, Project Library, Portland, Oregon.
- Boston Public Library, Copley Square, Boston, Massachusetts.
- Bowling Green State University, Library, Bowling Green, Ohio.
- Brigham Young University, A. C. Lambert, Librarian, Provo, Utah.
- British Ceramic Society, The Secretary, North Staffordshire Technical College, Stoke-on-Trent, England.
- Brookhaven National Laboratory, Research Library, Attention: Periodicals Sections, Upton, New York.
- Brooklyn Children's Museum, The Library, Brooklyn Avenue & Park Place, Brooklyn, New York.
- Brooklyn Public Library, Science and Industry Division, Grand Army Plaza, Brooklyn, New York.
- Brown University Library, Providence, Rhode Island.
- Brush Development Company, Att.: Lois A. Crane, Librarian, 3631 Perkins Avenue, Cleveland 14, Ohio.
- Brush Mineralogical Library, Kirtland Hall, Yale University, New Haven, Connecticut.
- Bryn Mawr College Library, Bryn Mawr, Pennsylvania.
- Buffalo Museum of Science, Research Library, Humboldt Park, Buffalo 11, New York.
- Building Materials Research, The Officer-in-Charge, Graham Road, Highett 321, Victoria, Australia.
- Bureau of Geology & Topography, The Library, Victoria Memorial Museum, Ottawa, Canada.
- Burgersdijk and Niermans, Boekhandel en Antiquariat, Templum Salomonis, Leiden, Netherlands.

Burma Educational Bookshop, P.O. Box 222, ABN Press Bldgs., 553 Merchant Street, Rangoon, Burma.

Burma National Planning Board, Executive Officer, Govt. of the Union of Burma, Ministry of National Planning, Prome Court, Rangoon, Burma.

California Division of Mines, Ferry Building, San Francisco 11, California.

California Institute of Technology, Pasadena, California.

California Research Corporation, Librarian, Box 446, La Habra, California.

California State Library, Library Courts Building, Sacramento, California.

Canadian Industries Ltd., Development Laboratory, Att: G. J. Harris, McMasterville, Quebec, Canada.

Canadian Refractories Ltd., Research Laboratory, Kilmar, Quebec, Canada.

Canterbury University College, The Librarian, Christ Church, New Zealand.

Carleton College Library, Northfield, Minnesota.

Carnegie Institute of Technology, Science Branch Library, Engineering Hall, Pittsburgh, Pennsylvania.

Carnegie Library of Pittsburgh, Periodical Division, Schenley Park, Pittsburgh, Pennsylvania.

Carnegie Museum, Schenley Park, Pittsburgh, Pennsylvania.

Case Institute of Technology, Dept. of Geology and Mineralogy, Cleveland, Ohio.

Centenary College Library, Shreveport 16, Louisiana.

Central Bibliotek, Dept. V. & W., Bandoeng, Java, N.E.I.

Central College Bangalore, Geology Department, re Mysore Government, Bangalore, Mysore, India.

Central Trust of China, Attention: Mr. T. K. Waung, Asst. Mgr., 112 Hongkong and Shanghai Bank Building, Hongkong, China.

Centralnaja Bibl-ka, Min. Chim. Prom, Ul Obucha 10, Moscow, U.S.S.R.

Centralnoi Bibliotke, Zvetnoi Metallurgii, Krymsky Val 3 pom. 423, Moscow, U.S.S.R.

Centre National de la Recherche Scientifique, Service Documentation, 45, Rue d'Ulm, Paris V, France.

Centr. Nauchno-Tekhnich., Biblioteka Chernoi Metallurgii, Jaroslavskoje shossa, 99, Moscow 164, U.S.S.R.

Centro Argentino de Ingerieros, Apartado 32, Correo Central, Buenos Aires, Argentina.

Ceylon, Government Mineralogist, Torrington Square, Colombo, Ceylon.

Chef du Service Geologique Regional de et a Costermansville, Belgian Congo.

Chicago Natural History Museum, Roosevelt Road and Field Drive, Chicago 5, Illinois.

Chinese Petroleum Corporation, Commissioner of Supplies K3-(36)-007(A), 131 Kiangsi Road, Shanghai, China.

Chief Engineer (Development), U. P., P.W.D. Irrigation Branch, Lucknow, U.P., India.

Civil Info. & Ed. Section (For U. S. Inf. Centers), GHQ. SCAP, APO 500, c/o P.M., San Francisco, California.

Claeys-Verheughe, Volderstraat 6, Ghent, Belgium.

Clark University Library, Worcester, Massachusetts.

Cleveland Public Library, 325 Superior Ave., N.E., Cleveland, Ohio.

College of the City of New York Library, Periodical Division, Convent Ave., and 139th Street, New York 31, N. Y.

Colorado College, Coburn Library, Colorado Springs, Colorado.

Colorado School of Mines Library, Golden, Colorado.

Colorado Springs Mineralogical Society, c/o Wulff Shoe Company, 123 N. Tejón Street, Colorado Springs, Colorado.

- Columbia University Libraries, South Hall, Columbia University, New York 27, N. Y.
 Commissioner of Lands and Mines, Georgetown, British Guiana.
 Commissioner of Mines, P.O. Box 339, Nairobi, Kenya.
 Connecticut Agricultural Experiment Station, General Library, P.O. Box 1106, New Haven 4, Connecticut.
 Consejo de Inv. Cientificas, Biblioteca General, Cambio International, Serrano 121, Madrid, Spain.
 Consejo Superior de Investigaciones Cientificas, Seccioc de Cambio Internacional, Serrano 121, Madrid, Spain.
 Consolidated Mining & Smelting Company of Canada Ltd. 1, Central Research Library, Trail Smelter, Trail, B. C., Canada.
 Corhart Refractories Company, 16th and Lee Streets, Louisville 10, Kentucky.
 Cornell University Library, Ithaca, New York.
 Cranbrook Institute of Science, Bloomfield Hills, Michigan.
 Crane Company, Research Laboratories, Miss Helen Basil, Librarian, 836 South Michigan Avenue, Chicago, Illinois.
 Creole Petroleum Corporation, Technical Library, Apartado 889, Caracas, Venezuela.
 Creole Petroleum Corporation, Apartado 172, Division Geologist, Maracaibo, Venezuela.
 Cristalerias Rigolleau, Att.: Sr. Roberto Suarez, Baseo Colon 800, Buenos Aires, Argentina S. A.

 Dalhousie University, The University Library, Halifax, Nova Scotia.
 Dartmouth College Library, Hanover, New Hampshire.
 Mr. Davidson, 9 Castlegate, Penrith, Cumberland, England.
 Dekker en Nordmann's Wetenschappelijke Boekhandel N.V., O. Z. Voorburgwal 243, Amsterdam, Holland.
 Denver Public Library, Science and Engineering Dept., Denver, Colorado.
 Departamento de Minas y Petroleo, Casilla 3967, Santiago, Chile.
 Department of Mines, Parliament Bldgs., Victoria, British Columbia, Canada.
 Dept. Public Info., USAMGIK (For U. S. Info. Centers), APO 235-2, c/o P.M., San Francisco, California.
 Departamento Nacional de Producao Mineral (Bibliotheca), Avenida Pasteur 404, Rio de Janeiro, Brazil, S. A.
 DePauw University Library, Greencastle, Indiana.
 Detroit Public Library, 5201 Woodward Ave., Detroit 2, Michigan.
 Direccion General de Minas, Lamadrid 438, Jujuy, Argentina, South America.
 Director-General, Posts & Telegraphs GPO, Treasury Gardens, Melbourne, C. 2, Australia.
 Distribution Section, ISD, OMGUS, Frankfurt, APO 757, c/o PM, New York, N. Y.
 Division Materials Testing Laboratory, U. S. Engineer Office, Box 51, Marietta, Georgia.
 Division des Mines et de Geologie, Service Geologie, Rabat, Morocco.
 Division of Industrial Chemistry, The Chief, Lorimer St., Fishermen's Bend, Melbourne S.C. 8, Victoria, Australia.
 Dominion Laboratory, Director, 111 Sydney Street, Wellington, New Zealand.
 Dow Chemical Company Library, Midland, Michigan.
 Duke University Library, Duke Station, Durham, North Carolina.
 Durham Colleges in the Univ. of Durham, Librarian, Science Laboratories, South Road, Durham, England.

 Earlham College Library, Richmond, Indiana.
 East Bay Mineral Society, Inc., P.O. Box 1196, Oakland 4, California.

- Eastman Kodak Company, Att.: Maurice H. Van Horn, Bldg. 59, Kodak Park Works, Rochester 4, New York.
- Ecole Nationale Supérieure des Mines, Bibliothèque, 60 Blvd. St. Michel, Paris VI, France.
- Ecole Polytechnique, 1430 Rue St. Denis, Montreal, Canada.
- Electronic Water Treatment Corporation, 196 Morgan Street, Jersey City 2, N. J.
- Emory University, The Geology Club, Emory University, Georgia.
- Emory University, The Library, Emory University, Georgia.
- Empire Zinc Company, Hanover, New Mexico.
- Engineering Societies Library, 29 West 39th Street, New York 18, N. Y.
- Engineers Library, Eng. Experimental Station, College Station, Texas.
- Era Branch, OMGUS, Att.: Mr. Jacobs, Smithsonian Warehouse, APO 742 A, c/o Postmaster, New York, N. Y.
- Erich Eichner & Cia. Ltda. (for Augusto Probst), Rua Rosario 135/137, Caixa Postal 3481, Rio de Janeiro, Brazil, S. A.
- Escola Nacional de Minas e Metalurgia, Biblioteca, Ouro Preto, Minas Gerais, Brazil.
- Escola Politécnica, Biblioteca da Universidade de São Paulo, Praça Coronel Fernando Prestes, 153, São Paulo, Brazil, S. A.
- Escuela de la Ingeniería de la Universidad de Cuyo, San Juan, Argentina.
- Ethyl Corporation, Development Section Library, P.O. Box 341, Baton Rouge 1, Louisiana.
- Eti Bank, Ankara, Turkey.
- Fabrica de Ladrillos Industriales y Refractories, S.A., Monterrey, N.L., Mexico.
- Faculté Polytechnique de Mons, Bibliothèque, Rue de Houdain, Mons, Belgium.
- Felix Montenegro, Inc., Bais, Negros Oriental, P. I.
- Fondational Universitaire, Library, 11 Rue d'Egmont, Brussels, Belgium.
- Foot Mineral Company, 10 East Cheltenham Avenue, Philadelphia 44, Pennsylvania.
- Ford Motor Company, Library, Engineering Laboratory, Dearborn, Michigan.
- Franklin & Marshall College, Library, Lancaster, Pennsylvania.
- Free Public Library, Fourth & "D" Streets., San Bernardino, California.
- Free Library of Philadelphia, Periodical Dept., Middle City West District, Philadelphia 3, Pennsylvania.
- Fresno State Teachers College Library, Fresno, California.
- Fund. Bib-ka Akad. Nauk, Kommunalnaja 4, Riga, U.S.S.R.
- Fund. Bib-ka Akad. Nauk, Ul. Dzerzhinskogo 8, Tbilisi, U.S.S.R.
- Garden State Minerals, 1034 Bloomfield Street, Hoboken, New Jersey.
- General Chemical Company, L. H. Lab. Library, P.O. Box 149, Long Island City, New York.
- General Electric Company Laboratory, Library, Pittsfield, Massachusetts.
- General Electric Company, Research Laboratory Library, Schenectady, New York.
- General Electric Company, Research Laboratories, Wembley, England.
- Geological Institute, Academia Sinica, Chi-Ming-Ssu, Nanking, China.
- Geological Museum, Trondhjemsveien 23, Oslo 45, Norway.
- Geological Society of America, 419 West 117th Street, New York 27, N. Y.
- Geological Society of London, Library, Burlington House, Piccadilly, London W. 1, England.
- Geological Survey of Canada, Library, Dept. of Mines and Resources, Victoria Memorial Museum, Ottawa, Canada.
- Geological Survey of Egypt, The Director, Darwin Post Office, Cairo, Egypt.
- Geological Survey of Great Britain, Library, Exhibition Road, London S. W. 7, England.

- Geological Survey of India, Director, 27 Chowinghee Road, Calcutta, India.
- Geological Survey of Kiangsi, Pei-Hwa-Chow Road, Nanchang, China.
- Geological Survey of New Zealand, Director, 156, The Terrace, Wellington, C. I., New Zealand.
- Geological Survey of Nigeria, The Director, Kaduna Junction, Nigeria.
- Geological Survey of South Africa, Box 401, Pretoria, South Africa.
- Geological Survey of Southern Rhodesia, The Director, Salisbury, Southern Rhodesia, Africa.
- Geological Survey of Taiwan, Box 31, Taipeh, Taiwan, China.
- Geological Survey of Uganda, Director, P.O. Box 9, Entebbe, Uganda.
- Geophysical Laboratory, 2801 Upton Street, N.W., Washington 8, D. C.
- Georgia Dept. of Mines, Mining and Geology, 425 State Capitol, Atlanta, Georgia.
- Georgia School of Technology Library, Atlanta, Georgia.
- Gleerupska, A. B., Univ.-Bokhandeln, Lund, Sweden.
- Gos. Izdatelstvo Inostranno, Literature, Novo-Alexeevskaja Ul 52, Moscow, U.S.S.R.
- Gos. Nauch. Biblioteka, Min. Vys. Obrazovanija, Pl. Nogina. 2/5, Moscow, U.S.S.R.
- Gosudarstvennaja Biblio-teka S.S.S.R., im Lenina, ul. Kalinina, 3, Moscow, U.S.S.R.
- Government Metallurgical Laboratory, University of the Witwatersrand, Johannesburg, South Africa.
- H. Hagerup's Boghandel, Postgiro Konto 371, Copenhagen, Denmark.
- Haagens, Gerard E., Room 607, 597 Fifth Ave., New York 17, New York.
- Hagan Corporation, Att. R. C. Cibella, Librarian, 323 Fourth Ave., Pittsburgh 22, Pennsylvania.
- Hamilton College Library, Clinton, New York.
- Harvard College Library, Serial Division, Cambridge 38, Massachusetts.
- Harvard University, Mineralogical Library, Cambridge 38, Massachusetts.
- Hebrew University, Dept. of Geology, Jerusalem, Palestine.
- Hoganas-Billesolms A/B, Biblioteket, Hoganas, Sweden.
- The Hughes, The Lodge, Minera, Wrexham, North Wales, Great Britain.
- Humble Oil & Refining Co., Miss May Q. Garthar, Box 2180, Houston 1, Texas.
- Hunter College Library, 695 Park Avenue, New York 21, New York.
- ICD-OMG W/Baden, US, Info Center Stuttgart, Oper Freiburg F Zone, APO 154, c/o PM, New York.
- ICD-OMG W/Baden, US, Info Center Stuttgart, Oper Mainz F Zone, APO 154, c/o PM, New York.
- Idaho State College Library, Pocatello, Idaho.
- Idaho University Library, Moscow, Idaho.
- Illinois State Geological Survey, 419 Natural Resources Bldg., Urbana, Illinois.
- Illinois State Museum, Centennial Bldg., Springfield, Illinois.
- Imperial Chemical Industries, Ltd., Alkali Division, Supply Dept., Northwich, Cheshire, England.
- Imperial Chemical Industries, Ltd., Billingham Division, Library, Main Offices, Billingham Co. Durham, England.
- Imperial College of Science and Technology, South Kensington, 18 Cromwell Place, London S.W. 7, England.
- Indiana University Library, Bloomington, Indiana.
- Indian School of Mines, Dhanbad, India.
- Industrial Distributors, Ltd. Diamond Research Department, St. Andrew's House, 32-34 Holborn Viaduct, London, E.C. 1, England.

Industrial Distributors, Ltd., Box 916, Johannesburg, Transvaal, South Africa.
 Instituto de Geologia, Casilla 2777, Santiago, Chile, S. A.
 International Annual Tables, Dr. N. Thon, Institute de Chemie, 18 Rue Pierre-Curie, Paris, France.
 International Minerals and Chemical Corporation, Library, 20 North Wacker Drive, Chicago 6, Illinois.
 International Nickel Company of Canada, Ltd., Att.: Director of Research, Copper Cliff, Ontario, Canada.
 Iowa State College Library, Ames, Iowa.

Jadypur College, Librarian, College of Engineering and Technology, Calcutta, India.
 James E. Morrow Library, Marshall College, Huntington 1, West Virginia.
 Johannesburg Public Library, Johannesburg, South Africa.
 John Crerar Library, Technology Department, Chicago 1, Illinois.
 Johns Hopkins University Library, Baltimore, Maryland.
 Johns-Manville Research Laboratories, Att.: Mrs. B. R. Smalley, Librarian, Manville, New Jersey.
 Joliet High School Science Department, Joliet, Illinois.
 Jones and Laughlin Steel Corporation, Att.: F. X. Tartaron, Box 189, Negaunee, Michigan.

K. Tekniska Hogskolans Bibliotek, Stockholm 26, Sweden.
 Kansas City Public Library, 9th and Locust Street, Kansas City, Missouri.
 Kansas State Agricultural College, The Library, Manhattan, Kansas.
 Keninklijke Bibliotheek, Lang, Voorhout 34, The Hague, Holland.
 M. Keough Futi Surprise Mine, Cr. Shiff and Jacobson, Box 65, Gwelo, So. Rhodesia.
 Kennecott Copper Corporation, McGill, Nevada.
 Knizhnyj Otdel Akademii Nauk, Ul. Kropotkina 16, Moskva 34, U.S.S.R.
 Kungl. Vetenskapsakademiens Bibliotek, Stockholm 50, Sweden.

Laboratorio Quimico Nacional, Apartado 2577, Bogotá, Colombia.
 Lafayette College Library, Easton, Pennsylvania.
 Lehigh University Library, Bethlehem, Pennsylvania.
 Leopoldville, Monsieur le Chef du Service Geologique Regional de Leopoldville, Congo Belge, Africa.
 Librairie Falk Fils, 22 Rue des Paroissiens, Brussels, Belgium.
 Librairie Jos. R. Vilimek, Bratislava, Czecho-Slovakia.
 Library of Congress, Washington, D. C.
 Libreria del Colegio S. A. (for Inst. de Geologia y Minería), Alsina 500, Buenos Aires, Argentina, S. America.
 Linda Hall Library, 5109 Cherry Street, Kansas City 4, Missouri.
 Linde Air Products Co. Library, East Park Drive & Woodward Avenue, Tonawanda, New York.
 Linde Air Products Co., Corundum Plant, Columbus Drive and Kennedy Ave., East Chicago, Indiana.
 Livraria Kosmos (for Faculdade de Filosofia), Caixa Postal 3481, Rua do Rosario 135-137, Rio de Janeiro, Brazil.
 Livraria Kosmos, Rua Marconi 91-93, Sao Paulo, Brazil, S. A.
 Livraria Kosmos (for Experimentacao e Pesquisas), Rua Marconi 91-93, Sao Paulo, Brazil.

- Los Angeles City College, Att.: Librarian, 855 No. Vermont Avenue, Los Angeles 27, California.
- Los Angeles County Museum, Exposition Park, Los Angeles 7, California.
- Los Angeles Public Library, 650 West Fifth Street, Los Angeles 13, California.
- Louisiana State University Library, University, Louisiana.
- Lucknow University, Librarian, Lucknow, India.
- M. Paul Phillips Library, Birmingham-Southern College, Birmingham 4, Alabama.
- Magnolia Petroleum Company, Att.: Mr. T. W. Nelson, Field Research Department, P.O. Box 900, Dallas 1, Texas.
- Maine Mineralogical and Geological Society, Miss Jessie L. Beach, Secretary, 6 Allen Avenue, Portland, Maine.
- Makassar Filiaal van het Alg. Proefastation voor den Landbouw, Makassar, Celebes, Indonesia.
- Marietta College Library, Marietta, Ohio.
- Masaryk University, Att.: Prof. Joseph Sekanina, Kounicova 63, Brno, Czechoslovakia.
- Massachusetts Institute of Technology Library, Cambridge 39, Massachusetts.
- Massachusetts State College, Amherst, Massachusetts.
- McGill University, Library, 3459 McTavish St., Montreal, Canada.
- McMaster University Library, Hamilton, Ontario, Canada.
- Mechanics Mercantile Library, Mechanics Institute, 57 Post Street, San Francisco, California.
- Metal Mining Administration, National Resources Commission, North Chungshan Road, Hungchiso, Nanking, China.
- Metropolitan-Vickers Electrical Co., Ltd., The Librarian, Research Dept., Trafford Park, Manchester 17, England.
- Metropolitan Water Sewerage & Drainage Board, The Secretary, 341 Pitt Street, Sydney, N.S.W., Australia.
- Mezhdunarodnaia Kniga Ekspeditsia, Kuznetskii Most, 18, Moscow, U.S.S.R.
- Miami University Library, Oxford, Ohio.
- Michigan College of Mines and Technology, Library, Houghton, Michigan.
- Michigan State College Library, East Lansing, Michigan.
- Midwest Research Institute, Att.: G. Garland, Librarian, 4049 Pennsylvania Ave., Kansas City, Missouri.
- Milwaukee Public Library, 814 West Wisconsin Avenue, Milwaukee 2, Wisconsin.
- Mineral Exploration Bureau, National Resources Commission of China, 3 Chiangchun-miao, Tingchiachiso, Nanking, China.
- Minerals Unlimited, 1724 University Ave., Berkeley, California.
- Mineral Resources Survey, Director, Canberra, A.C.T., Australia.
- Minnesota Mining & Manufacturing Co., Library, 367 Grove Street, St. Paul, Minnesota.
- Ministere des Mines, Chambre E-605, Hotel du Gouvernement, Quebec, Canada.
- Ministry of Supply Director, Royal Aircraft Establishment, Farnborough Hants, England.
- Missouri School of Mines and Metallurgy, Library, Rolla, Missouri.
- Monsanto Chemical Company, Library, Central Research Dept., Dayton 7, Ohio.
- Montana School of Mines, Butte, Montana.
- Montana State University Library, Missoula, Montana.
- Morganite Crucible Co. Ltd., Battersea Church Road, London, S.W. 11, England.
- Mount Holyoke College Library, South Hadley, Massachusetts.
- Mt. San Antonio College, Library, Pomona, California.

Museo Argentino de Ciencias Naturales, Bernardino Rivadavia, Buenos Aires, Argentina.
 Museo Civico di Storia Naturale, Marco de Marchi, Milano, Italia.
 Museum National d'Histoire Naturelle, Bibliotheque Centrale, 36 Rue Geffroy St. Hilaire,
 Paris 5, France.
 Museum of Natural History, City Library Assn., Springfield, Massachusetts.

Natal University, College Library, Box 1525, Durban, South Africa.
 National Central Library, Cheng Hsien Kai, Nanking, China.
 National Central University, Department of Geology, Sye Pai Lou, Nanking, China.
 National Chekiang University Library, Hangchow, Chekiang, China.
 National Geological Survey of China, 942 Chukiang Road, Nanking, China.
 National Geological Survey of China, Northwestern Branch, Chung-Shan-Lin, Lanchow,
 Kansu, China.
 National Geological Survey of China, Peiping Branch, 9 Ping Ma Ssu, West City, Peiping,
 China.
 National Institute of Health, Director, Rockville Pike, Bethesda, Maryland.
 National Lead Company, The Librarian, Titanium Division, P.O. Box 58, South Amboy,
 New Jersey.
 National Library of Peiping, 1 Wen Tsin Chieh, Peiping, China.
 National Museum, Russell Street, Melbourne C 1, Victoria, Australia.
 National Pei-Yang University Library, Att.: Dept. of Geology, Tientsin, China.
 National Peking University, The Library, Peiping 9, China.
 National Sun Yat Sen University, College of Science, Canton, China.
 National Tsing Hua University Library, Peiping, China.
 Natural History Museum, The Keeper, Mineral Library, South Kensington, London, S.W.
 7, England.
 Nautschnaja Biblioteka, Akademii Nauk Kaz SSR, Ul. Kalinina, 49, Alma-Ata, U.S.S.R.
 Naval Ordnance Laboratory Library, White Oak, Silver Spring, Maryland, Att.: Librarian.
 Naval Research Laboratory, Library, Washington 25, D. C.
 Neftjanovj, Biblioteke, B. Kaluzhskaia 6, Moscow, U.S.S.R.
 New England Museum of Natural History, M. B. Cobb, Librarian, 109 Chestnut Street,
 Boston 8, Massachusetts.
 New Jersey Zinc Company, 160 Front Street, New York, N. Y.
 New Jersey Zinc Company Library, Franklin, New Jersey.
 New Jersey Zinc Company, Empire State Division, Gilman, Colorado.
 New Jersey Zinc Company, Technical Library, Palmerton, Pennsylvania.
 New Mexico Highlands University, Las Vegas, New Mexico.
 New Mexico State School of Mines, Socorro, New Mexico.
 New Mexico State Teachers College, Silver City, New Mexico.
 New York Mineralogical Club, Inc. c/o F. H. Pough, Secretary, American Museum of
 Natural History, New York City.
 New York Public Library, 476 Fifth Avenue, New York, N. Y.
 New York State College of Ceramics, Alfred, New York.
 New York State Library, Albany 1, New York.
 New York University Library, University Heights, New York, N. Y.
 New York University, Washington Square Library, 100 Washington Square East, New
 York, N. Y.
 Newark Museum, Washington Park West, Newark, New Jersey.
 Nijhoffs, N. V. Martinus, Lange Voorhout 9, The Hague, Holland.
 Norges Geologiske Undersøkelse, Josefinesgt 34, Oslo, Norway.

- North Carolina State College of Agriculture and Engineering, W. P. Kellam, Librarian,
State College Station, Raleigh, North Carolina.
- North Dakota Agricultural College, The Library, Fargo, North Dakota.
- North Texas Agricultural College, Library, Arlington, Texas.
- Northwestern University Library, Evanston, Illinois.
- Oberlin College Library, Oberlin, Ohio.
- Occidental College Library, Los Angeles 41, California.
- Ohio River Division Laboratories, Corps of Engrs., Dept. Army, 5851 Mariemont Avenue,
Cincinnati 27, Ohio.
- Ohio State University Library, Columbus 10, Ohio.
- Ohio University Library, Athens, Ohio.
- Ohio Wesleyan University, Slocum Library, Delaware, Ohio.
- Oklahoma Agricultural and Mechanical College Library, Stillwater, Oklahoma.
- Oliver Iron Mining Co., Research Laboratory, 4832 Grand Avenue, Duluth, Minnesota.
- Ontario Dept. Mines, Parliament Bldgs., Toronto, Ontario, Canada.
- Oregon, State Department of Geology and Mineral Industries, 702 Woodlark Building,
Portland 5, Oregon.
- Oregon State Agricultural College Library, Corvallis, Oregon.
- Osterreichisch-Amerikanische Magnesit A. G., Radenthein, Karsten, Austria.
- Ottawa University Library, Ottawa, Kansas.
- Owens-Illinois Glass Co., Research Library, 1700 N. Westwood Ave., Toledo, Ohio.
- Oxford University, Radcliffe Library, Oxford, England.
- Pacific Mineral Society, Roy Milligan, Librarian, 649 South Olive Street, Los Angeles 14
California.
- Panhandle A. & M. College Library, Goodwell, Oklahoma.
- Panstwowy Instytut Geologiczny W Warszawie, Warsaw, Poland.
- Pasadena City College, Physical Science Dept., 1570 E. Colorado, Pasadena 4, California.
- Paterson Museum, Mr. Wm. C. Casperson, 268 Summer Street, Paterson, New Jersey.
- Pennsylvania State College, School of Mineral Industries, State College, Pennsylvania.
- Philadelphia Mineralogical Society, Academy of Natural Science, Logan Circle, Phila-
delphia, Pennsylvania.
- Phillips University Library, Enid, Oklahoma.
- Pilkington Brothers Ltd., Buyers Dept., Lancashire, St. Helens, England.
- Pimentel & Casquilho, Booksellers, Rue Eugenio dos Santos 75, Lisboa, Portugal.
- Pomona College Library, Claremont, California.
- Presidency College, The Principal, Madras, India.
- Princeton University Library, Princeton, New Jersey.
- Publichnaja Biblioteka im. Saltykova-Tshedrina, Sadovaja ul. 18, Leningrad, SSSR.
- Purdue University Agricultural Experiment Station Library, Lafayette, Indiana.
- Purdue University Library, Lafayette, Indiana.
- Queens Mineral Society, Mr. Wm. Stadler, Secretary, 153-08 119th Avenue, Barsley Park,
Long Island, New York.
- Queen's University Library, The Douglas Library, Kingston, Ontario, Canada.
- R. Univerita, Istituto di Mineralogia, Via dei Verdi, is.° 216, Messina, Italy.
- R. Universita, Istituto di Mineralogia, Via della Universita, Modena 5, Italy.
- R. Universita di Padova, Istituto di Mineralogia, Corso Garibaldi g Padova, Italia.

- R. Università di Pisa, Istituto di Mineralogia, Pisa Italy.
 Rautaeikirjakauppa Oy (Hukkala), Koydenpunojankatu 2, Helsinki, Finland.
 Revue de Geologie, M. le Secrétaire General, Laboratoire de Geologie, Université de Liège, Liège, Belgium.
 Rhode Island State College Library, Green Hall, Kingston, Rhode Island.
 Rhodes University College, The Librarian, Grahamstown, South Africa.
 Rice Institute Library, P.O. Box 1892, Houston 1, Texas.
 Rochester Public Library, 115 South Avenue, Rochester, New York.
 Rosenberg and Sellier, 14 Via Andrea Doria, Torino, Italy.
 Rotamsted Experimental Station, Harpensen, Herts, England.
 Roth & Cie., F. & Cie., S.A., Pepinet 5, Lausanne, Switzerland.
 Royal Ontario Museum of Mineralogy, 100 Queen's Park, Toronto 5, Canada.
 Royal Technical College, The Librarian, Andersonian Library, George Street, Glasgow, Scotland.
 Rutgers University Library, New Brunswick, New Jersey.
- St. Louis University, Institute of Geophysical Technology, The Library, 3621 Olive Street, St. Louis 8, Missouri.
 St. Paul Public Library, Order Department, 4th and Washington Streets, St. Paul 2, Minnesota.
 St. Peters College, Students Library, Jersey City 6, New Jersey.
 Salonica University Library, Mr. P. Formozis, Director, Salonica, Greece.
 Salt Commissioner, Colombo, Ceylon.
 San Diego Society of Natural History, Balboa Park, San Diego, California.
 San Diego State College Library, San Diego, California.
 San Francisco Public Library, Civic Center, San Francisco 2, California.
 Santa Ana Public Library, Santa Ana, California.
 Santa Barbara State College, 1920 Lausen Road, Santa Barbara, California.
 Saranac Laboratory, 7 Church Street, Saranac Lake, New York.
 Sault Ste Marie Branch Library, Michigan College of Mining and Technology, Sault Ste Marie, Michigan.
 Scholtens en Zoon, Groote Markt 43, Groningen, The Netherlands.
 Schortmann's Minerals, 6 McKinley Avenue, Easthampton, Massachusetts.
 Science Museum Library, Accessions Dept., South Kensington, London, S.W. 7, England.
 Scientific Library Division, The Chief, Bureau of Science, Manila, P. I.
 Scripps Institute of Oceanography, The Library, La Jolla, California.
 Sektor Seti Bibliotek, Akademii Nauk S.S.R., Ul Marska Engeljsa 11, Moskva 19, S.S.S.R.
 Service des Mines, Noumea, New Caledonia.
 Servicio Tecnico de Minería y Geología, Att.: Victor M. Lopez, Ministerio de Fomento, Caracas, Venezuela, S. A.
 Servico de Documentacao, Ministerio da Agricultura, Caixa Postal 915, Rio de Janeiro, Brasil.
 Servico de Informacao Agricola, Ministerio da Agricultura, Caixa Postal 1523, Rio de Janeiro, Brazil, S. America.
 Servicio Geologico Nacional, Apartado Nacional No. 2504, Bogotá, Colombia, S. A.
 Shell Oil Company, Expl. & Prod. Research, 3737 Bellaire Blvd., Houston 5, Texas.
 Siam Dept. of Mines, Director, Krung Kasem Road, Sapan Khao, Bangkok, Siam.
 Smith, W. H. and Sons, 71-75 Boulevard Adolph Max, Brussels, Belgium.
 Smith College Library, Northampton, Massachusetts.
 Sociedad Científica Argentina, Santa Fe 1145, Buenos Aires, Argentina.

- Socony Vacuum Oil Co. of Colombia, Apartado Aereo 4034, Bogotá, Colombia.
- South African Council for S & I Research, Library & Information Division, Provate Bag 189, Pretoria, South Africa.
- South Dakota State School of Mines, Library, Rapid City, South Dakota.
- Southern Methodist University, Library Dept., Dallas, Texas.
- Southwestern Louisiana Institute, Stephens Memorial Library, Lafayette, Louisiana.
- The Southwest Mineralogists, Att.: Pearle Arnold, Librarian, 2132 West 76th Street, Los Angeles 44, California.
- Spencer Lens Company, Buffalo, New York.
- Squier Signal Laboratory, Director, Att.: Librarian, Fort Monmouth, New Jersey.
- Stanford University Library, Stanford University, California.
- State Normal School Library, Gorham, Maine.
- State University of Iowa, Library, Iowa City, Iowa.
- State University of North Dakota Library, University Station, Grand Forks, North Dakota.
- Steven, B. F. and Brown, 28-30 Little Russell Street, London W. C. 1, England.
- Sul Ross State Teachers College, The Library, Alpine, Texas.
- Sveriges Geologiska Undersökning, Stockholm 50, Sweden.
- Syracuse University Library, Syracuse, New York.
- TB/2652, Antonin Klapa, Tovarna Obuvi, Prostějov, Travnická 12, Czechoslovakia.
- TB/2652, Pl N. P. Zavod, Kbely, U. Prahy, Czechoslovakia.
- Technical Periodical Club, Att : Librarian, Bureau of Reclamation, Denver 2, Colorado.
- Technical University of Norway, Geological Department, c/o Professor Dr. Thorolf Vogt, Trondheim, Norway.
- Technicke Knihkupectvi, Janska I, Praha I, Czechoslovakia.
- Tennessee Eastman Corporation, Kingsport, Tennessee.
- Texas Christian University Library, Fort Worth, Texas.
- Texas College of Mines and Metallurgy, Library, El Paso, Texas.
- Texas Technological College Library, Lubbock, Texas.
- Thin, James, 54-56 South Bridge Street, Edinburgh 1, Scotland.
- Thomas and Hochwalt Laboratories, Monsanto Chemical Company, Dayton, Ohio.
- Toledo Public Library, 325 Michigan Street, Toledo 2, Ohio.
- Trinity University Library, San Antonio 1, Texas.
- Tropical Oil Company, Exploration Dept., Apartado 335, Bogotá, Colombia, S. A.
- Tufts College Library, Medford 55, Massachusetts.
- Twining Laboratories, Library, P.O. Box 1472, Fresno 16, California.
- UACCO, Lumnite Division, Buffington Station, Gary, Indiana.
- Union Carbide and Carbon Research Laboratories, Inc., 4625 Royal Avenue, P.O. Box 580, Niagara Falls, New York.
- Union College Library, Schenectady, New York.
- Union Miniere du Haut Katanga, ST/Bibl., Elisabethville, Belgian Congo.
- U. S. Atomic Energy Commission, P.O. Box 42, Murray Hill Station, New York 16, N. Y.
- U. S. Atomic Energy Commission, P.O. Box E, Oak Ridge, Tennessee.
- U. S. Atomic Energy Commission, Technical Library, Public Health Service Building, 1901 Constitution Ave., N.W., Washington 25, D. C.
- U. S. Bureau of Mines, Albany, Oregon.
- U. S. Bureau of Mines, Intermountain Experiment Station, University of Utah, Salt Lake City, Utah.

- U. S. Bureau of Mines, Petroleum & Oil-Shale Experiment Station, Box 621, Laramie, Wyoming.
- U. S. Bureau of Standards Library, Washington, D. C.
- U. S. Geological Survey, The Librarian, Washington 25, D. C.
- U. S. Information Center (Vienna), ISB Hq. USFA, APO 777, c/o PM, New York, N. Y.
- U. S. National Museum, Washington, D. C.
- Universidad de Tucumán, Biblioteca Central, Ayacucho 482, Tucumán, Argentina.
- Universita' di Cagliari, Istituto di Mineralogia, Cagliari, Italy.
- Universita, Istituto di Mineralogia, Piassa S. Marco L. Firenze, Italy.
- Universita, Istituto Mineralogia e Petrografia, Via Botticelli 23, Milano, Italy.
- Universita, Istituto di Mineralogia, Via Archiradi 36, Palermo, Italy.
- Universita, Istituto di Mineralogia, Sassari, Sardinia.
- Universitaetsbibliothek, (17a) Heidelberg, American Zone, Germany.
- Universitaetsbibliothek, (20) Goettingen, British Zone, Germany.
- Universitaetsbibliothek, (21) Muenster, Germany.
- Universitaetsbibliothek, Dr. Karl Lueger Ring 1, Wien I.M., Austria.
- Université de Paris, Monsieur le Conservateur de la Bibliotheque, Sorbonne, Rue des Ecoles, Paris V, France.
- Université Sorbonne de Paris, Bibliotheque, 47 Rue des Ecoles, Paris V, France.
- Université de Strasbourg, Laboratoire de Mineralogie et Petrographie, 1 Rue Blessig, Strasbourg, France.
- Universitetet, Oslo, Norway.
- Universiteits-Bibliotheek, Singel 421, Amsterdam, Holland.
- Universitetsbiblioteket, Lund, Sweden.
- Universitetets Mineralogiske Museum, Voldgade 7, Copenhagen K., Denmark.
- Universitetsbibliotekets II Afd., Tidsskriftkontoret, Norre Alle 49, Copenhagen, Denmark.
- University, The Librarian, Adelaide, South Australia.
- University, The Librarian, Edgbaston, Birmingham 15, England.
- University College, The Librarian, Potchefstroom, Transvaal, South Africa.
- University College of the S. W. of England, The Librarian, Roborough Library, Prince of Wales Road, Exeter, England.
- University College of Swansea Library, Singleton Park, Swansea, England.
- University Library, Stellenbosch, South Africa.
- University of Arizona Library, Tucson, Arizona.
- University of Arkansas, General Library, Fayetteville, Arkansas.
- University of Berne, Mineralog, Petro. Institut, Berne, Switzerland.
- University of British Columbia, Library, Vancouver, British Columbia, Canada.
- University of Brussels Library, Avenue F. D. Roosevelt, Brussels, Belgium.
- University of Buffalo Library, 3425 Main Street, Buffalo, New York.
- University of Calcutta, Secretary Geological Department, Senate House, Calcutta, India.
- University of California Library, Berkeley 4, California.
- University of California, Division of Soils, 120 Hilgard Hall, Berkeley 4, California.
- University of California, Los Alamos Scientific Laboratory, Att.: Project Librarian, P.O. Box 1663, Los Alamos, New Mexico.
- University of California at Los Angeles, The Library, 405 Hilgard Avenue, Los Angeles 24, California.
- University of Cambridge, Dept. of Mineralogy and Petrology, Cambridge, England.
- University of Cambridge, Library, Cambridge, England.
- University of Cape Town, The Librarian, J. W. Jagger Library, Rodebosch, Cape Town, South Africa.

- University of Chattanooga Library, Chattanooga, Tennessee.
University of Chicago Libraries, Periodical Division, Harper M 26, Chicago, Illinois.
University of Cincinnati, Mr. Peter Scherrer, Director of Central Stores, Cincinnati 21, Ohio.
University of Cincinnati, The General Library, Cincinnati 21, Ohio.
University of Colorado Library, Boulder, Colorado.
University of Connecticut, Wilbur L. Cross Library, Storrs, Connecticut.
University of Florida Library, Gainesville, Florida.
University of Georgia, General Library, Serials Division, Athens, Georgia.
University of Hawaii, Library, Honolulu, Hawaii.
University of Illinois Library, Urbana, Illinois.
University of Kansas Library, Periodical Dept., Lawrence, Kansas.
University of Leeds, Leeds, Yorkshire, England.
University of Louvain Library, 102 Bis rue de Namur, Louvain, Belgium.
University of Maine Library, Orono, Maine.
University of Manchester Library, Manchester, England.
University of Manitoba, Science Library, Winnipeg, Manitoba, Canada.
University of Melbourne, Central Library, Carlton N. 3, Victoria, Australia.
University of Miami, Library, Att.: Wm. G. Harkins, Coral Gables, 34, Florida.
University of Michigan, General Library, Ann Arbor, Michigan.
University of Minnesota Library, Minneapolis 14, Minnesota.
University of Missouri, General Library, Columbia, Missouri.
University of Montreal, Dept. of Geology, 2900 Mount Royal Blvd., Montreal, Canada.
University of Nebraska Libraries, Lincoln 8, Nebraska.
University of Nevada Library, Reno, Nevada.
University of New Hampshire, Library, Durham, New Hampshire.
University of New Mexico Library, Albuquerque, New Mexico.
University of North Carolina Library, Chapel Hill, North Carolina.
University of Notre Dame, Notre Dame, Indiana.
University of Oklahoma Library, Norman, Oklahoma.
University of Oregon Library, Eugene, Oregon.
University of Otago, Librarian, Dunedin N.1, New Zealand.
University of Pennsylvania Library, Philadelphia, Pennsylvania.
University of Pittsburgh, University Library Room 530, Cathedral of Learning, Pittsburgh, Pennsylvania.
University of Pretoria, Pretoria, South Africa.
University of Queensland, Library, Brisbane, Queensland, Australia.
University of Reading, The Librarian, Reading, England.
University of Rochester Library, Rochester, New York.
University of St. Andrews Library, St. Andrews, Scotland.
University of Sheffield, Applied Science Library, St. George's Square, Sheffield 1, England.
University of South Carolina, Periodical Room, McKissock Memorial Library, Columbia, S. C.
University of South Dakota Library, Vermilion, South Dakota.
University of Southern California, Library, University Park, Los Angeles, California.
University of Stockholm, Mineralogical Department, Drottninggatan 116, Stockholm, Sweden.
University of Sydney, Fisher Library, Sydney, New South Wales, Australia.
University of Tennessee, Library, Knoxville 16, Tennessee.
University of Texas, Library, Serials Acquisition, Austin, Texas.

University of Thessaloniki, Salonika, Greece.
University of Toronto, Library, Toronto 5, Ontario, Canada.
University of Tulsa, 7th and College, Tulsa, Oklahoma.
University of Utah Library, Salt Lake City, Utah.
University of Virginia, Alderman Library, Charlottesville, Virginia.
University of Washington Library, Acquisitions Division, Seattle 5, Washington.
University of Washington, College of Mines, 324 Mines Laboratory, Seattle, Washington.
University of West Virginia Library, Morgantown, West Virginia.
University of Western Australia, The Librarian, Perth, Western Australia.
University of Wisconsin, Periodicals Division, General Library, Madison 6, Wisconsin.
University of the Witwatersrand, Main Library, Milner Park, Johannesburg, South Africa.
University of Wyoming Library, Laramie, Wyoming.

Valentin Garcia y Cia, Apartado 2103, Habana, Cuba.
Vanadium Corporation of America Library, Bridgeville, Pennsylvania.
Vanderbilt University, Joint University Library, Nashville, Tennessee.
Victoria University College, Library, Wellington, New Zealand.
Virginia Military Institute, Library, Lexington, Virginia.
Vsesojuznyj Institut, Mineral'nogo Syrja, Pyzhevskij per 7, Moscow, U.S.S.R.

Ward's Natural Science Establishment, 3000 Ridge Road East, Rochester, New York.
Washington State College Library, W. W. Foote, Librarian, Pullman, Washington.
Washington University Library, St. Louis, Missouri.
Wayne University Library, 4841 Cass Avenue, Detroit 1, Michigan.
Waynesboro College Library, Waynesburg, Pennsylvania.
Wellesley College Library, Wellesley 81, Massachusetts.
B. Wepf & Cie., Booksellers, Basle, Switzerland.
Wesleyan College Library, 175 North Street, Middletown, Connecticut.
Western Australia, State Government Stores Dept., Fremantle, Western Australia.
Western State College of Colorado, Library, Gunnison, Colorado.
Wichita City Library, Wichita, Kansas.
Willamette University Library, Salem, Oregon.

Young, Henry and Sons, Ltd., 15 North John Street, Liverpool, England.

NOTES AND NEWS

PSEUDOTACHYLITE OF THE ANTIETAM QUARTZITE

J. L. ANDERSON, *The Johns Hopkins University, Baltimore, Maryland.*

INTRODUCTION

The material which forms the basis of this paper was first encountered by Ernst Cloos during the course of field studies in Frederick County, Maryland. The quarry from which the specimens were collected is located in the Antietam quartzite approximately 8 miles south of the town of Frederick and 3 miles west of Sugar Loaf Mountain on the west side of the Monocacy River. The author later accompanied Ernst Cloos to the locality at which time further studies were made and additional material secured.

GENERAL DESCRIPTION

The Antietam quartzite of lower Cambrian age is lead gray to brownish gray in color. In the vicinity of the Monocacy River, the rock shows evidence of faulting and is cut by numerous veins which have a preferred orientation (Fig. 1). These veins, which represent tension cracks, have been filled with chlorite, chlorite and quartz, and occasionally with only quartz. The majority of them contain chlorite and their dark greenish black appearance suggested tachylite veins in the field. The veins vary in width from 1 to 1/16 inch (Fig. 2). The small veins are usually elliptical

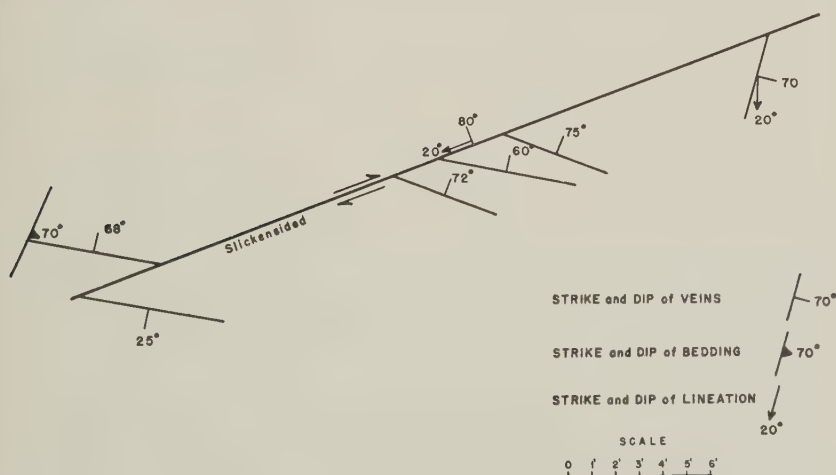


FIG. 1. Relationship of veins and faulting in Antietam quartzite near Monocacy River, 8 miles south of Frederick, Md.

and are usually less than 1 foot in length. Drusy structures have been encountered in several instances, with well formed quartz crystals growing perpendicular to the vein wall. In the abandoned quarry, on the south side of the road near the river, a small fault is present. Bedding dips 70 degrees to the southeast and is obliquely cut by tension cracks on both sides of the fault plane (Fig. 1).

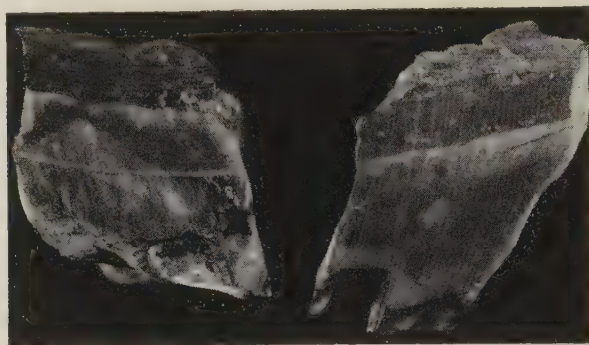


FIG. 2. Chlorite veins (upper dark area) in Antietam quartzite.

MICROSCOPIC CHARACTERISTICS

The Antietam quartzite possesses a granoblastic structure and is composed of subangular grains of quartz with subordinate albite-twinned plagioclase and microcline. Blue-green tourmaline, zircon, and biotite are accessory minerals. In thin section the rock has a dirty appearance and the mineral grains are surrounded by slivers of sericite and chlorite, yellow iron oxide, and argillaceous matter.

Microscopically, the quartzite appears to be relatively undeformed. The quartz grains possess a faint undulatory extinction but no suggestion of crushing and annealing of the grains was noted. The presence of chlorite and sericite and the relatively undeformed character of the grains suggests that regionally the rock belongs to a low stage of metamorphism.

In most instances the vein material consists of chlorite with subordinate quartz. The quartz grains occur as small individuals distributed throughout the chlorite but occasionally large masses are present. At the boundaries of large masses of chlorite and quartz, chlorite seems to filter into the quartz. A rhythmic development of these two minerals was also noted, with small worm-like chlorite masses arranged in hexagonal outlines within large quartz grains. Large quartz masses are usually highly deformed (Anderson, 1945), the deformation being more pronounced when chlorite is subordinate in amount (Fig. 3).

The beta index of refraction of the vein chlorite is 1.641. The optic angle, $2V$, is very small and the mineral is negative. The pleochroism is:

Z = deep yellowish green

Y = pale yellowish green

The retardation, measured by means of a Berek compensator, was $206\text{ m}\mu$, corresponding to a birefringence of approximately 0.006. Re-

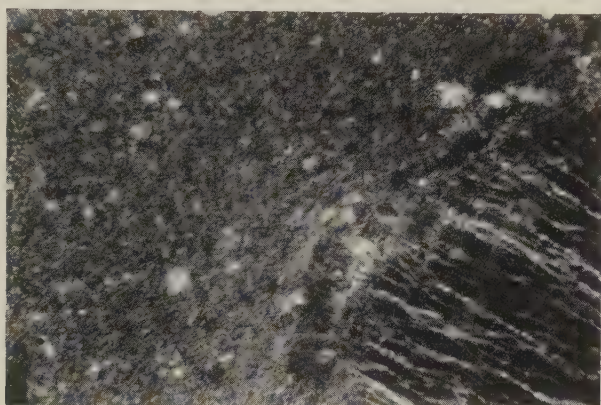


FIG. 3. Thin section of vein chlorite showing deformed character of large quartz and distribution of small quartz. Crossed nicols.

ferring these data to Winchell's curves (Winchell, 1933, p. 278) the composition of the vein chlorite is:

Ferroantigorite ($\text{H}_4\text{Fe}_3\text{Si}_2\text{O}_9$) = 34%

Daphinite ($\text{H}_4\text{Fe}_2\text{Al}_2\text{SiO}_9$) = 33%

Antigorite ($\text{H}_4\text{Mg}_3\text{Si}_2\text{O}_9$) = 17%

Amesite ($\text{H}_4\text{Mg}_2\text{Al}_2\text{SiO}_9$) = 16%

This information indicates that the vein chlorite is of the iron-rich variety.

Chlorite of the Antietam quartzite was isolated and studied. The beta index and birefringence was found to be the same as that of the vein chlorite, hence the composition of both is identical.

CONCLUSIONS

The composition of the dark colored veins, which represent the filling of tension cracks caused by faulting, is essentially chlorite and quartz. The term pseudotachylite has been applied in this instance to emphasize the resemblance of the vein-filling to that of basaltic glass. Diabase dikes are present approximately two miles east of the locality under discussion

but no evidence of igneous activity was observed in the immediate vicinity. The mineral character of the vein-filling and the absence of evidence of igneous activity does not favor an igneous origin of these veins.

Shand (1916) has discussed the origin of pseudotachylite of Parijs, Orange Free State. Here, granite gneiss is cut by numerous veins of black rock which resembles tachylite. It was Shand's opinion that the pseudotachylite originates from the granite gneiss through melting "caused not by shearing but by shock, or, alternatively, by gas-fluxing" (Shand 1916, p. 219).

Pseudotachylites have been reported from Madras, Scotland, and Argentina (Shand, p. 209). In every instance, faulting seems to have been associated with the development of these rocks and no direct evidence of igneous activity was present.

The pseudotachylite of the Antietam quartzite is thought to have originated through faulting. The boundaries between the country rock and the vein are sharp and microscopically chlorite is usually well developed along the contact. The similarity in composition between chlorite of the quartzite and that of the vein-filling suggests that the chlorite was derived from the quartzite. The rise in temperature due to faulting is thought to have caused the migration of ions of chlorite and quartz from the quartzite into the tension cracks thus producing small veins resembling tachylite. Adjustment along these veins after they were filled resulted in the deformation of the quartz.

REFERENCES

- ANDERSON, J. L. (1945), Deformation planes and crystallographic directions in quartz: *Geol. Soc. Am., Bull.*, **56**, 409-430.
- SHAND, S. J. (1916), The pseudotachylite of Parijs (Orange Free State), and its relation to 'Trap-Shotten Gneiss' and 'Flinty Crush-Rock': *Quart. Jour. Geol. Soc. London*, **72**, 198-221.
- WINCHELL, A. N. (1933), *Elements of Optical Mineralogy*: John Wiley & Sons, Inc., New York.

A NEW LOCALITY FOR LUDLAMITE*

JEWEL J. GLASS AND JOHN S. VHAY, *U. S. Geological Survey,
Washington, D. C.*

Ludlamite, a hydrous iron phosphate, has been found in the copper-cobalt deposits in the Blackbird district, Lemhi County, Idaho. This discovery of ludlamite establishes a third verified occurrence of this mineral in the United States, the first two from New Hampshire were described by Wolfe (10, 11). Ludlamite was first discovered at the Wheal Jane mine in Cornwall in 1877 (3). Since that time this mineral has been found once in Japan (4), once in Colombia (2), and has been reported from Bavaria (8) under the name "lehnerite," which has been shown by Berman (1) to be ludlamite.

The Blackbird district is in the east-central part of Idaho, about 20 miles southwest of Salmon, the nearest town of any size. The district is accessible by graded dirt and gravel roads from Salmon and Challis. The nearest railroad is at Darby, Montana, 105 miles away.

Ludlamite in the Blackbird district is intimately associated with dark blue vivianite crystals, pyrite, quartz, calcite, and siderite. It occurs in vugs and in veinlets in the sulfide ore consisting of pyrrhotite, chalcopyrite, pyrite, and cobaltite, along with minor minerals including safflorite, tourmaline, apatite, micas, and carbonates. A detailed description of the occurrence of the ludlamite is contained in a Strategic Minerals report on the district by John S. Vhay (9).

The ludlamite crystals are pale sea-green, transparent, and are remarkably free from inclusions. They are monoclinic basal tablets, with prominent *c* (001) faces, and perfect basal cleavage. The crystals are usually about 8 millimeters across, although some of them are 12 millimeters across, and most of them are 4 millimeters thick. When heated the ludlamite crystals exfoliate rapidly into thin basal plates, indicating a definite lamellar structure. The results of three determinations of specific gravity made on the Berman microbalance are $G.=3.15$, 3.17 , and 3.18^a ; and a determination on the same sample made by the Adams-Johnston pycnometer method shows $G.=3.152^b$. The specific gravity value (3.72) in Larsen's (5) tables, 1921 edition, and copied in the 1934 edition (6), is a misprint for $G.=3.12$. (Field's (3) original work on ludlamite shows $G.=3.12$). Optically ludlamite is biaxial positive.^c The

* Published by permission of the Director, U. S. Geological Survey.

^a Determinations by Geo. Switzer, U. S. National Museum.

^b Determination by J. J. Fahey, U. S. Geological Survey.

^c In the original description of ludlamite by Field (3), Professor Maskelyne of the British Museum contributed the crystallographic and optical data, in which he stated that

optical axial angle for the Blackbird ludlamite is large, $2V = 86^\circ$. $Z \wedge c$ is large. $Y = b$. The indices of refraction measured by the immersion method in white light are: $\alpha = 1.651$, $\beta = 1.669$, $\gamma = 1.690$. Optical data are in agreement with those recorded in the literature, especially for the Palermo (New Hampshire) and the Hagendorf (Bavaria) material.

No quantitative chemical work has been done in the Geological Survey on ludlamite from the Blackbird district, but a qualitative spectrographic examination^d indicates that the mineral is almost a pure iron phosphate.

REFERENCES

1. BERMAN, HARRY, The identity of "lehnerite" and ludlamite: *Am. Mineral.*, **10**(11) 428-429 (1925).
2. CODAZZI, RICARDO LLERAS, Concreciones cristalinas de la arenisca de Bogata: *Contribucion al Estudio de los Minerales de Colombia. Imprenta de la Crusada, Bogata*, 8-9 (1915).
3. FIELD, FREDERICK, On ludlamite, a new Cornish mineral: *Philos. Mag. and Jour. Sci., London, Edinburgh, and Dublin*, **3**, 15 (5th series), 52-57 (1877).
4. FUKUCHI, NOBUYO, An iron phosphate from the Ashio Copper Mine: *Beitrag zur Mineralogie von Japan*, **4**, 192-194 (1912).
5. LARSEN, ESPER S., JR., Microscopic Determination of Nonopaque Minerals: *U. S. Geol. Survey, Bull.* **679**, 223 (1921).
6. LARSEN, ESPER S. JR., and BERMAN, HARRY, Microscopic Determination of Nonopaque Minerals: *U. S. Geol. Survey, Bull.* **848**, 124 (1934).
7. MASKELYNE, N. STORY, Note on the optical characters of ludlamite: *Philos. Mag. and Jour. Sci., London, Edinburgh, Dublin*, **3**, 16 (5th Ser.) 135-138; **3**, 21 (5th Ser.) 525 (1877).
8. MÜLLBAUER, F., Die phosphatpegmatite von Hagendorf i. Bayern: *Zeit. Kryst. Min.*, **61**, 331-336 (1925).
9. VHAY, JOHN S., Cobalt-copper deposits of the Blackbird District, Lemhi County, Idaho: *U. S. Geol. Survey, Strategic Minerals Investigation, Preliminary Report*, 3-219 (1948).
10. WOLFE, C. WROE, Ludlamite from North Groton, New Hampshire: *Am. Mineral.*, **32** (3-4), 211-212 (1947). (Abstract).
11. WOLFE, C. WROE, Ludlamite from the Palermo Mine, North Groton, New Hampshire: *Am. Mineral.*, **34** (1-2), 94-97.

the optical character of ludlamite was negative. However, Maskelyne (7) redetermined the optical character of ludlamite on a better crystal of the same material and found that "The optical character (of ludlamite) is positive."

^d Examination by K. J. Murata, U. S. Geological Survey.

PROCEEDINGS OF SOCIETIES

MINERALOGICAL SOCIETY (LONDON)

A meeting of the Society was held Thursday, November 25, 1948, in the apartments of the Geological Society of London, Burlington House, Piccadilly, W.1 (by kind permission). The following papers were presented:

(1) BARYTE BEARING NODULES FROM THE MIDDLE LIAS OF THE EAST MIDLANDS.

By Dr. J. H. Taylor.

In parts of Leicestershire, Rutland and Northamptonshire the *margaritatus* zone of the Middle Lias contains a series of carbonate nodules. Some are of "cemenistone" type, consisting largely of fine-grained calcite, others of "clay-ironstone" type, in which the carbonate is chalybite (containing approximately 80% FeCO_3). In their septarian cracks the nodules contain widespread baryte, calcite, blende and pyrite. The structure of the mineral infillings of these cracks is illustrated and their paragenesis discussed.

(2) X-RAY STUDIES OF HALLOYSITE AND METAHALLOYSITE. PART I. THE STRUCTURE OF METAHALLOYSITE, A RANDOM LAYER STRUCTURE.

By Dr. G. W. Brindley and Mr. K. Robinson.

The x-ray powder diagram of metahalloysite consists of basal reflections, 001, and two-dimensional diffraction bands, hk . No reflections of type hkl occur. The basal reflections indicate a layer spacing of 7.2\AA . The two-dimensional bands are interpreted quantitatively by application of Warren's theory of diffraction by two-dimensional layer structures. The results show that the layer has the same structure and dimensions as the layers in other kaolin minerals, and that the linear dimensions of the crystalline sheets are of the order of $150\text{--}200\text{\AA}$. This appears to be the first quantitative study of such diffraction bands.

(3) X-RAY STUDIES OF HALLOYSITE AND METAHALLOYSITE. PART II. THE TRANSITION OF HALLOYSITE TO METAHALLOYSITE IN RELATION TO RELATIVE HUMIDITY.

By Dr. G. W. Brindley and Mr. J. Goodyear.

Two methods are described of determining the interlayer water content of halloysite and metahalloysite: (a) a weighing method, (b) an x-ray method, involving the use of the Hendricks-Teller theory of reflections by statistical arrangements of kaolin and water sheets. It is shown that in atmospheres of controlled humidity the water content of both minerals is variable. In the driest atmospheres, the formula of metahalloysite approximates to $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\frac{1}{2}\text{H}_2\text{O}$. The results are compared with published analyses.

(4) X-RAY STUDIES OF HALLOYSITE AND METAHALLOYSITE. PART III. THE EFFECT OF TEMPERATURE AND PRESSURE ON THE HALLOYSITE-METAHALLOYSITE TRANSITION.

By Dr. G. W. Brindley, Mr. K. Robinson and Mr. J. Goodyear.

The (001) spacing of metahalloysite produced at low temperatures or in dry atmospheres is of the order of $7.4\text{--}7.5\text{\AA}$. By heating to 450°C ., this spacing is progressively reduced to 7.25\AA , approximately the value for kaolinite. This is interpreted in terms of the expulsion of the residual water layers in the 7.5\AA -metahalloysite. By application of pressures up to 75,000 lbs./sq. in., a large measure of dehydration of halloysite is obtained. Orientation of the crystallites is produced. Geological implications are considered.

(5) CRYSTALLISATION OF BASALTIC MAGMA AS RECORDED BY
VARIATION OF CRYSTAL-SIZE IN DIKES.

By Dr. H. G. F. Winkler. (To be taken as read.)

Across a dike, curves representing the size variation of crystals which have crystallised in various temperature ranges, are given. A number of these diagrams constructed for different thicknesses of dikes are used for comparison with the graph showing the variation of crystal-sizes actually observed in nature. Measurements of the sizes of plagioclase, pyroxene and magnetite at various distances from the walls of the Cleveland dike (Great Ayton, Yorkshire) have been carried out. The three curves representing crystal-size at various distances are characteristically different and can be compared with the constructed diagrams and thus interpreted. The characteristic shape of the curves found in the dike is explained. Furthermore, it becomes possible to establish the temperature ranges in which the three minerals have crystallised in the magma. Taking into account the actual quantities of crystallised minerals a table is given showing the temperature ranges and the quantities of minerals crystallised in the magma during the cooling process. The results are in full accordance with physico-chemical and petrographical studies.

(Titles and abstracts submitted by G. F. Claringbull, General Secretary)

NEW MINERAL NAMES

Merumite

SMITH BRACEWELL, The geology and mineral resources of British Guiana. Handbook of natural resources of British Guiana 1946, Sect. 4, pp. 18-40; through *Mineralog. Abs.*, **10**, 292 (1948). "A new chromium mineral named merumite, found in small quantity in the Merume river basin, Mazaruni district, gave SiO_2 1.30, TiO_2 0.75, Cr_2O_3 81.30, Al_2O_3 6.55, total iron as Fe_2O_3 1.58, MnO 0.06, V_2O_5 0.15, $\text{H}_2\text{O} +$ 8.08, $\text{H}_2\text{O} -$ 0.10; sum 99.87%. Sp. gr. 4.49." (This corresponds to $4(\text{Cr},\text{Al})_2\text{O}_3 \cdot 3\text{H}_2\text{O}$, or perhaps $\text{Cr}_2\text{O}_3 \cdot \text{H}_2\text{O}$. M.F.)

Mansfieldite

VICTOR T. ALLEN AND JOSEPH J. FAHEY, *Am. Mineral.* **33**, 122-134 (1948).

Loughlinite

JOSEPH J. FAHEY AND J. M. AXELROD, *Am. Mineral.*, **33**, 195 (1948) (abs.).

Scorzalite

W. T. PECORA AND J. J. FAHEY, *Am. Mineral.*, **33**, 205 (1948) (abs.); *Am. Mineral.*, **34**, 83-93 (1949).

Souzalite

W. T. PECORA AND J. J. FAHEY, *Am. Mineral.*, **33**, 205 (1948) (abs.); *Am. Mineral.*, **34**, 83-93 (1949).

M. F.

NEW DATA

Elpasolite

CLIFFORD FRONDEL, *Am. Mineral.*, **33**, 84-87 (1948).

DISCREDITED MINERALS

Hagemannite (= Ralstonite + Thomsenolite)

CLIFFORD FRONDEL, *Am. Mineral.*, **33**, 84-87 (1948).

Amosite (= Actinolite)

JOHN C. RABBITT, *Am. Mineral.*, **33**, 263-323 (1948).

Bidalotite (= Anthophyllite)

JOHN C. RABBITT, *Am. Mineral.*, **33**, 263-323 (1948).

Billietite = (variety of Becquerelite)

ALFRED SCHOEP AND SADI STRADIOT, *Am. Mineral.*, **33**, 703-705 (1948).

Yenerite (= Boulangerite)

S. C. ROBINSON, *Am. Mineral.*, **33**, 716-723 (1948).

Falkmanite (= Boulangerite)

C. ROBINSON, *Am. Mineral.*, **33**, 716-723 (1948).

M. F.

ANNOUNCEMENT OF THE THIRTIETH ANNUAL MEETING OF THE
MINERALOGICAL SOCIETY OF AMERICA

The thirtieth annual meeting of the Society will be held at El Paso, Texas, November 10-12, 1949, in connection with the sixty-second annual meeting of the Geological Society of America.

Members of the Society who are planning to present papers at the scientific sessions of the annual meeting should notify the Secretary in order to receive the proper blanks for their abstracts. All abstracts must be in the Secretary's office by *September 1*. By ruling of the Council only abstracts of papers to be presented orally will be acceptable, and, at the discretion of the Program Committee, no author will be allowed more than 15 minutes or to present more than one volunteer paper.

Advance announcement of the annual meeting has already been distributed to members of the Society by the Geological Society of America. Further information regarding the meeting will be mailed, with the ballot for officers, in September.

NOMINATIONS OF OFFICERS FOR 1950

At its meeting in 1948, the Council nominated the following Fellows as officers of the Mineralogical Society of America for the year 1950, to be voted on by the membership at the annual election:

President: George Tunell, University of California at Los Angeles, California.

Vice-President: Ralph E. Grim, Illinois Geological Survey, Urbana, Illinois.

Secretary: C. S. Hurlbut, Jr., Harvard University, Cambridge, Massachusetts.

Treasurer: Earl Ingerson, U. S. Geological Survey, Washington, D. C.

Editor: Walter F. Hunt, University of Michigan, Ann Arbor, Michigan.

Councilor (1950-53): E. F. Osborn, School of Mineral Industries, Pennsylvania State College, Pennsylvania.

NOMINATING COMMITTEE

The officers and fellows of the Mineralogical Society of America are nominated by the Council at its annual meeting. The Council is guided in its choice by recommendations made by the Nominating Committee. The members of this committee are listed below so that those wishing to make recommendations for officers and fellows can communicate with one of the members.

Samuel G. Gordon, *Chairman*, Philadelphia Academy of Natural Sciences, Philadelphia, Pennsylvania.

Leonard G. Berry, Dept. of Mineralogy, Queen's University, Kingston, Ontario, Canada.

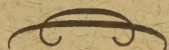
Harry H. Hess, Dept. of Geology, Princeton University, Princeton, New Jersey.

Duncan McConnell, Gulf Research & Development Company, P.O. Drawer 2038, Pittsburgh, Pennsylvania.

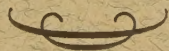
Walter H. Newhouse, Dept. of Geology, University of Chicago, Chicago, Illinois.

C. S. HURLBUT, JR., *Secretary*

NOTICE OF POSTPONEMENT



We sincerely regret that through circumstances beyond our control we are compelled to postpone our Exhibition and Sale of Fine Minerals as advertised in the last issue of this journal.



SCHORTMANN'S MINERALS

6-10 MCKINLEY AVE.

EASTHAMPTON, MASS.

WARD'S Fine Minerals

For The COLLECTOR

Again, Ward's is pleased to offer some of the new and fine mineral specimens for the collector. For specimens of unusual quality and beauty, for mineralogy equipment, always look to Ward's . . . make Ward's your headquarters!

ASTROPHYLLITE, El Paso County, Colorado. Attractive large brown blades in quartz. Specimens average 2×2 to $2\frac{1}{2} \times 3\frac{1}{2}$ " and are priced from \$.75, \$1.00, \$1.50; 3×4 to 4×5 ", \$2.00, \$2.50.

BARITE, Cow Green Mine, Teesdale, England. Large white partly transparent crystal groups ranging from $2\frac{1}{2} \times 3$ to $3\frac{1}{4}$ to 5" priced at \$2.00, \$2.50, \$3.00; $4 \times 4\frac{1}{2}$ to 3×5 ", \$3.50, \$4.00, \$4.50.

BARYTOCALCITE, Alston Moor, Cumberland, England. Good specimens of this rare carbonate with small monoclinic crystals on xline barytoalcite. Specimens average $2 \times 2\frac{1}{2}$ to 3×4 " and are priced at \$2.00, \$2.50, \$3.00, \$3.50, \$4.00.

COLORADOITE, Kirkland Lake, Ontario, Canada. Massive mercuric telluride with free gold in rock. $1\frac{3}{4} \times 2\frac{1}{4}$ ", \$8.00.

MELONITE, Robb-Montbray Mine, Montbray Twp., Quebec. Nickel telluride in rich xline masses with free gold in rock. $\frac{3}{4} \times 1\frac{1}{4}$ ", \$10.00; $2 \times 2\frac{1}{4}$ ", \$35.00.

SELENIUM. Native selenium formed by sublimation of selenium from pyrite and arsenopyrite in rocks adjacent to the burning Greta Coal Seams at Mt. Wingen, New South Wales. Black globular masses averaging $\frac{1}{8}$ to $\frac{1}{4}$ " are priced at 10 for \$2.00.

SYLVANITE, Kapnik, Transylvania. Xled and xline masses on rock $3\frac{1}{2} \times 5\frac{1}{4}$ ", \$17.50.

All prices are F.O.B. Rochester, N.Y.

WARD'S FINE MINERAL SPECIMENS, CATALOG FM 1, has just recently been issued. It lists new acquisitions from domestic and foreign sources. Write for this free catalog today.

GRAIN-THIN SECTIONS OF MINERALS AND MULTIPLE ORIENTED SECTIONS

A valuable new teaching aid for teachers of optical mineralogy and petrography—developed by Rudolf Von Huene, distributed by Ward's. Mr. Von Huene's technique in developing this new series of slides is described in an article in the Jan.-Feb. issue of *The American Mineralogist*. *WPS 10 Complete set of 40 grain-thin sections and 4 multiple oriented sections . . . \$110.00

* Write for Ward's Natural Science Bulletin, Vol. XXII, No. 2, November 1948 for complete information about the contents of this new series.

WARD'S NATURAL SCIENCE ESTABLISHMENT, INC.
Serving the Natural Sciences Since 1862
3000 Ridge Road East • Rochester 9, New York